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A revision of the Australian fossil species of *Zoila* (Gastropoda: Cypraeidae)

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Abstract

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Zoila Jousseaume, 1884 is a cowry genus, the species of which are now confined to the coastal waters of Western Australia and southern Australia. Six fossil species are known from southeast Australia, of which three are new, ranging in age from late Oligocene to middle Miocene, known from the Murray, Otway and Bass basins. Three fossil species are known from Western Australia, of which three are new, ranging in age from late Eocene to late Pliocene, known from the Carnarvon, Bremer and Eucla basins. *Umbilia (Gigantocypraea)* Schilder 1927 (type species *Cypraea gigas* McCoy) is regarded as a synonym of *Zoila*. The earliest record of the genus is *Z. chathamensis* (Cernohorsky, 1971), Paleocene/early Eocene, Chatham Islands, probably ancestral to the Australian fossils. *Zoila* is closely related to *Cypraeorbis* Conrad, 1865, of which *Bernaya* Jousseaume, 1884 is regarded as a synonym. Living species are known to have no planktotrophic larval stage, so there is considerable variation in species morphology. Such direct development arose in these cowries at least as early as the late Eocene. Fossils described here are *Zoila viathomsoni* sp. nov., *Z. didymorhyncha* sp. nov., *Z. glomerabilis* sp. nov., *Z. dolichorhyncha* sp. nov., *Z. mulderi* (Tate, 1892), *Z. platypyga* (McCoy, 1876) (= *consobrina* McCoy, *toxorhyncha* Tate, *platypyga simplicior* Schilder), *Z. gigas* (McCoy, 1867) (= *dorsata*, *gabrieli*), *Z. campestris* n. sp. and *Z. fodinata* n. sp.

Keywords

Gastropoda, Cypraeidae, cowries, Australia, Tertiary, new species, taxonomy

Introduction

Zoila is a member of a group of Australian cowries that includes *Notocypraea*, *Umbilia* and *Austrocypraea*, the members of which all seem to have direct larval development rather than having a planktotrophic larval stage as in most species of cowry (Wilson, 1985; Wilson and Clarkson, 2004). This paper reports research results that continue from a study of the Australian endemic genus *Umbilia* (Darragh, 2002).

Subfamily classification

The genus *Zoila* is usually placed in the subfamily Bernayinae Schilder, 1927 erected for the fossil genus *Bernaya* Jousseaume, 1884, of which Zoilinae Iredale, 1935 is a synonym (Wilson and Clarkson, 2004). Meyer (2003), in his work on molecular systematics of cowries, retained most of the subfamilies previously used by many authors on the family, but did not place the genus *Zoila* in any subfamily (although his Table 3 could imply a placement in the subfamily Bernayinae). However, following further molecular work, he subsequently (Meyer, 2004) placed the genera *Zoila* and *Barycypraea* within the subfamily Bernayinae. Cypraeorbinae Schilder, 1927 was erected for the fossil genus *Cypraeorbis* Conrad, 1865. I consider that *Bernaya* is a synonym of *Cypraeorbis*, as argued below. Therefore, if subfamilies are regarded as useful in classification, Cypraeorbinae should be used instead. Bouchet and Rocroi (2005) included the subfamilies Bernayinae and Cypraeorbinae, along with three other subfamilies, within the synonymy of Gisortinae Schilder, 1927, erected for the genus *Gisortia* Jousseaume, 1884. Species of *Gisortia* have an obsolete fossula, quite different from those of species of *Cypraeorbis* and *Zoila*, so this synonymy is unlikely.

Nomenclatural history of *Zoila* fossil species

The genus *Zoila* was established by Jousseaume (1884a) for three species of large living cowries from Western Australia. The first fossil species later assigned to this genus were described by Frederick McCoy from the Tertiary of Victoria. *Cypraea gigas* was described by McCoy in 1867 without illustration and in 1875, it was redescribed, figured and placed in the subgenus *Aricia*. Two more species, *Cypraea (Aricia) platypyga* and *C. (A.) consobrina* were described and figured by McCoy in 1876 and 1877, respectively. In 1890, Tate revised these three species and added another two species, *C. toxorhyncha*, regarded here as a synonym of *Z. platypyga*, and *Cypraea dorsata*, regarded here as a synonym of *Z. gigas*. In 1892, Tate figured a new species *C. mulderi* and described it in 1893, pointing out its affinities with *C. platypyga*. Tate assigned all these species to *Cypraea*. Harris (1897) assigned

C. gigas and *C. platypyga* to the subgenus *Erosaria*, which he regarded as a senior synonym of *Aricia*. In 1912, Chapman described *Cypraea gabrieli*, regarded here as a synonym of *Z. gigas*.

Schilder (1927) erected *Gigantocypraea* as a subgenus of *Umbilia* with *C. gigas* McCoy as the type species. He also placed the other species mentioned by Tate in *Umbilia*. However, in 1930, Schilder raised *Gigantocypraea* to generic status and referred the other species to *Zoila*, but subsequently (Schilder, 1935) reduced *Gigantocypaea* to a subgenus of *Zoila* and added a new subspecies, *Z. (Z.) platypyga simplicior*, regarded here as a synonym of *Z. platypyga*.

Time range and distribution

Living species of *Zoila* are known only from the southern and western coasts of Australia. There are seven recognised species, with distribution ranging from Apollo Bay in Victoria westwards across the southern coast and up the west coast of Western Australia as far north as the West Kimberley district (Wilson and Clarkson, 2004). Fossil species of *Zoila* are more widespread. The earliest known species, recognised by this author, occurred in the Paleocene to early Eocene of the Chatham Islands, New Zealand. This species may have given rise to younger Australian species. The earliest Australian species Z. *viathomsoniae* sp. nov., recorded from the upper Eocene of southwest Western Australia, is probably an ancestor of the younger Australian species of *Zoila*, of which there are two groups: an eastern and a western group. The eastern group is known from southeast Australia, and ranged in age from late Oligocene to middle Miocene. This group is characterised by having prominently developed anterior and posterior canals and does not seem to be ancestral to any living species. The western group is known from Victoria, Western Australia, Indonesia and India, and ranged in age from middle Miocene to Recent.

The oldest known member of the western group occurred in the middle Miocene of Western Australia. It seems to be ancestral to *Z. campestris* sp. nov. from the Pliocene of Western Australia. This species is probably ancestral to some of the living species, in particular *Z. venusta* (Sowerby, 1846). Species somewhat similar to the Western Australian species are found in the Neogene of Indonesia and India. A single species, known from one fragmentary specimen, occurred in the late Miocene of Victoria.

Affinities

Generic distinction among cowries is subject to much controversy. Few features of the shell can be used to characterise species groups, particularly without knowing their anatomy and molecular biology. Even when this information is available, it is not always possible to apply this knowledge to include unequivocally fossil species in groups composed of living species. The fossula is one shell structure that does seem to vary sufficiently to be able to use it to some extent in supraspecific classification, and link fossil and living species.

The Australian fossil cowries treated here have a type of fossular morphology similar to that found in species assigned to four nominal genera: *Cypraeorbis* Conrad, 1865; *Bernaya* Jousseaume, 1884; *Zoila* Jousseaume, 1884; and *Barycypraea* Schilder, 1927. Of these four, only *Zoila* is based on a living species, and hence can be characterised on the basis of anatomy and genetics, although *Barycypraea* — based on a fossil species — has living representatives. The close morphological relationship between the first three genera was first recognised by Schilder (1926), who placed *Zoila* as a subgenus of *Cypraeorbis* and synonomised *Bernaya* with *Cypraeorbis*. Later, as his subdivisions of the Cypraeidae became smaller, and more genera were recognised on the basis of minor differences, Schilder (1941) placed the three genera in his subfamily Cypraeorbinae, with *Zoila* and *Bernaya* in the Tribe Bernayini, and *Cypaeorbis* in the Tribe Cypraeorbini. Dolin (1991) regarded *Zoila* as a possible subgenus of *Cypraeorbis* in the subfamily Bernayinae. In the present study, specimens of the type species of each of these genera, as well as some other species assigned to them, have been examined to determine possible affinities.

Cypraeorbis, type species *Cypraea sphaeroides* Conrad, 1848, was based on a species occurring in the lower Oligocene of the southwest United States of America. The genus ranges in age from late Eocene to at least early Miocene. The fossula (fig. 1B) of a *C. sphaeroides* specimen from Byram, Mississippi (USNM 498351) is deeply excavated and bounded by a prominent lateral ridge on the anterior side. Posterior to this lateral ridge is a slight notch in the fossula margin. The lateral ridge merges anteriorly with a very weak terminal ridge. Between the first columellar tooth and the terminal ridge there is a wide depression, which extends as a sulcus parallel with the terminal ridge into the fossula. The fossula (figs 1C, 3E–F) of a *Cypraeorbis ventripotens* (Cossmann, 1903) specimen — a species closely related to, if not synonymous with *C. sphaeroides* (MacNeil and Dockery, 1984) — from the upper Eocene, Town Creek, Jackson, Mississippi (Mississippi Geological Survey collection) is large, subrectangular, concave, with a prominent notch at the anterior end of the thickened interior edge. The terminal ridge, like that of *C. sphaeroides*, is weakly developed and runs into the interior of the aperture forming the anterior edge of the fossula as a prominent ridge. A well developed groove or sulcus between the first columellar tooth and the terminal ridge runs parallel to the terminal ridge into the fossula. Specimens of *Cypraea willcoxi* (Dall, 1890) and *Zoila arlettae* Dolin, 1991 from the Early Miocene Chipola Formation of Farley Creek, Florida (MNHN, Paris) were also examined. *Z. arlettae* Dolin has a fossula (fig. 3N) very similar to *C. sphaeroides* and *C. ventripotens*, though larger and with a broader notch. *Cypraea wilcoxi* Dall is very close in morphology to *Z. arletti* and also has a fossula (fig. 3O) similar in structure to *Cypraeorbis sphaeroides* and *C. ventripotens*, hence both *Cypraea arlettae* and *Zoila wilcoxi* seem to be better placed in *Cypraeorbis* rather than in *Zoila* as suggested by Dolin (1991).

Petuch (2004) erected two new genera in the subfamily Cypraeorbinae, *Floradusta* (type species *Cypraea heilprini* Dall, 1890, early Miocene, Florida) and *Loxacypraea* (type species *Cypreaea chilona* Dall, 1900, early Miocene, Florida). He included in these genera several species that had been included by Dolin (1991) in *Cypraeorbis*, *Zoila*, *Siphocypraea* and *Erronea (Adusta)*. Petuch stated that a fossula was absent in

species of the two genera. This statement is incorrect, as shown by the descriptions and illustrations in Dolin and by my own observations of two of the species, *Cypraeorbis arlettae* and *C. wilcoxi* (see figs 3H–J, N, K, O). Revision of American taxa is beyond the scope of this paper, but I consider that *Floradusta* and *Loxacypraea* are synonyms of *Cypraeaorbis*, as the type species of each have a fossula similar to *C.sphaeroides* and *C. ventripotens*. Some of the other species included in *Floradusta* by Petuch (2004) are unlike species of *Cypraeorbis* in that the fossula is crossed by extensions of the columellar teeth and therefore cannot belong in the Cypraeorbinae. These species are best left in the genera to which they were assigned by Dolin (1991).

Bernaya, type species *Cypraea media* Deshayes, 1835, was based on a species from Valmondois in the Paris Basin, Sables Moyens, Bartonian (late Eocene). The differences between *Cypraeorbis* and *Bernaya* are very slight. The fossula of specimens of *Bernaya media* (Deshayes) (figs 1A, 4B, F) from Bois du Roi, Auvers (MNHN), is large, subrectangular and concave. On the interior side, it is bounded by a prominent lateral ridge, in which there is a prominent anterior notch. The terminal ridge of the anterior canal extends into the interior of the aperture and merges with the lateral ridge of the fossula. A well-developed groove adjacent to the terminal ridge runs down into the fossula. This groove is partly obstructed by a columellar tooth, which merges with the terminal ridge. Specimens of *Cypraea bartonensis* Edwards, 1854 from Barton, Hampshire, England (NMV P310165-6) have a similarly structured fossula, but there are no columellar teeth obstructing the groove. In this respect, it closely resembles *Cypraeorbis ventripotens*. A specimen of *Cypraea splendens* Grateloup, 1827, from the Rupelian of Gaas, Landes, France (NMV P310168) also has a fossula identical to *C. ventripotens*.

MacNeil and Dockery (1984) described the protoconch of *C. sphaeroides* as having five whorls, some of which are sculptured with a fenestrate pattern. Dolin and Dolin (1983) have described and figured (figs 3 and 4) the protoconch of *Bernaya media* as having four whorls, which have a fenestrate sculpture on the last two whorls. This form of protoconch suggests a planktotrophic larval stage. As there are no significant distinguishing features between the two genera, it seems appropriate to synonymise *Bernaya* with *Cypraeorbis*.

The type species of *Zoila* is *Cypraea friendii* Gray, 1831, from the waters off Fremantle, Western Australia. Specimens of this species have a large spoon-shaped, deeply concave fossula (Wilson and Clarkson, 2004, pl. 47). The terminal ridge is not prominent, if at all present (on some specimens it is merely represented by a blunt thickening), and there is no prominent ridge bounding the edge of the fossula. There is also no groove running from the ventral surface down into the fossula, though there may be a gap between the labial teeth representing such a groove. There is no notch on the internal edge of the fossula. In these respects, it is unlike the American and European species; however, other species of Australian *Zoila* do have these features, but the edge of the fossula is not markedly notched, rather, merely indented (figs 1E–G).

The fossula in *Zoila chathamensis* (figs 1H, 5I–J) is weakly developed, smooth, broad, very slightly concave, slightly projecting, and bounded by a very weak terminal ridge. It resembles the fossula in *Z. didymorhyncha* sp. nov. Specimens of *Zoila viathomsoni* sp. nov. have a well-developed fossula (figs 1D, 5L) bounded by a prominent ridge and with a very weak indentation towards the anterior end. There is a very shallow sulcus running into the fossula. Specimens of *Zoila platypyga* (McCoy) have a fossula somewhat similar to *Z. friendii* but the edge of the fossula is more ridge-like. There is no sulcus extending into the fossula parallel to the terminal ridge. Specimens of *Z. didymorhyncha* sp. nov. (figs 1E, 6C) have a weak terminal ridge merging with the edge of the fossula and a shallow sulcus running parallel to it into the fossula. None of the Australian fossils have the well-defined fossular margin or the well-developed notch behind it that is present in the European and American species of *Cypraeorbis*.

Unlike the protoconchs of *Cypraeorbis* species, the protoconchs of species of *Zoila*, where known, are paucispiral, slightly tilted and smooth (Ranson, 1967, pl. 6, figs. 1-3; Wilson, 1998). The protoconch of *Z. platypyga* consists of one whorl slightly tilted from the axis of the shell. The protoconch of *Z. gigas* (McCoy) consists of two whorls, the first of which is irregular and granulated (figs 13E–F). In cross-section (figs 2A–C), the protoconchs of *Z. viathomsoni*, *Z. platypyga* and *Z. gigas* resemble cross-sections of protoconchs of *Umbilia* species (Darragh, 2002, fig. 1). This morphology suggests a protoconch formed from a partly chitinous whorl. Wilson (1985) has shown that living species of *Zoila* have direct development. The protoconchs of the fossils suggest that the fossils also had direct development and that the change from planktotrophic development to direct development had taken place by the late Eocene. Unfortunately, the protoconch of the earliest known species, *Z. chathamensis*, is unknown. *Zoila* species have direct larval development like the other Australian cowries referred to the genera *Austrocypraea* Cossmann, 1903, *Umbilia* Jousseaume, 1884 and *Notocypraea* Schilder, 1927. The last three genera are endemic to Australia and do not have a distribution in shallow tropical seas, whereas species of *Zoila* are known from tropical as well as temperate waters and also have been found in the lower Tertiary of New Zealand, and the upper Tertiary of Indonesia and India. *Austrocypraea*, *Umbilia* and *Notocypraea* seem to be representatives of an ancient southern group, whereas the distribution of *Zoila* suggests that its origin may have been Tethyan. Most tropical cowries are known to have planktotrophic larvae, which accounts for their widespread distribution in the Indo–Pacific realm. *Zoila* seems to have evolved from the widespread genus *Cypraeorbis*, whose species almost certainly had planktotrophic larvae, although the occurrence of a species of *Zoila* in the Chatham Islands as early as the Paleocene to early Eocene may suggest a southern origin.

Though the differences between the genera are slight, *Zoila* seems sufficiently different from *Cypraeorbis* to be maintained for the present. Wilson and Clarkson (2005) suggested that *Zoila* evolved in Asian waters from a directly developing Tethyan ancestor of the subfamily Bernayinae and migrated to Australia in Miocene time. However, the occurrence of species in Australia in the late Eocene and in the New Zealand region in the Paleocene/early Eocene suggests that *Zoila* evolved much earlier, probably from *Cypraeorbis* or some other closely related

taxon, such as *Protocypraea* Schilder, 1927, in the earliest Tertiary or even in the late Cretaceous. Species of *Cypraeorbis* (recorded as *Bernaya*) and *Protocypraea* have been recorded from the upper Cretaceous of North America by Groves (1990, 2004) and *Protocypraea* is also known from the upper Cretaceous of India and the Paleocene of Pakistan (Cox, 1930).

Schilder (1927) erected *Barycypraea* as a subgenus of *Zoila* with type species *Cypraea (Aricia) caputviperae* Martin, 1899 (probably a synonym of *Cypraea murisimilis* Martin, 1879) for a group of cowries known from the upper Tertiary of Indonesia and living in the Indian Ocean. Molecular biological studies of cowries by Meyer (2004) showed that the nearest living relatives of the Australian living *Zoila* species are the western Indian Ocean species of *Barycypraea* and he grouped both genera in the subfamily Bernayinae. He included no other living taxa in this subfamily. Species of *Barycypraea* have a similar fossula (fig. 3L) to *Zoila* species and they are known to be spongivores like *Zoila* (Liltved, 1989). Species of *Barycypraea* occur in South Africa, Pakistan, India and Indonesia, and range in age from Miocene to Recent (Kay, 1990). The morphology and biogeography of *Barycypraea* suggests an origin similar to that of *Zoila* and a probable common ancestry.

Terminology and repositories

Measurements are given as follows: L = total length of shell; W = width of shell; H = height of shell. Tooth counts are cited as LT = labral teeth and CT = columellar teeth. The terms left and right refer to the animal's true left and right sides, respectively.

All material used in this study, unless otherwise stated, is held in the collections of Museum Victoria, registration numbers with prefixes P (invertebrate palaeontology collection) and F (living mollusca collection). Localities are cited where possible using the Museum Victoria fossil locality register with prefix PL (listed in Beu and Darragh, 2001). Museum acronyms used for other material are as follows: BM(NH) = Natural History Museum, London; SAM T = Tate Collection, South Australian Museum, Adelaide; AMNZ = Auckland Museum, New Zealand; AM C = Australian Museum, Sydney, New South Wales; WAM = Western Australian Museum; USNM = Smithsonian Institution, National Museum of Natural History; MNHN = Muséum national d'Histoire naturelle, Paris; GNS TM = GNS Science (New Zealand).

All specimens figured were coated with ammonium chloride for photography, unless stated otherwise.

Class **Gastropoda**

Family **Cypraeidae Rafinesque**, 1815

Subfamily **Cypraeorbinae** Schilder, 1927

Zoila Jousseaume, 1884

Zoila Jousseaume, 1884a:14.— Jousseaume, 1884b:89.— Cossmann, 1903:146, 149.— Thiele, 1929:275.— Schilder, 1935:336.— Schilder and Schilder, 1939:173.—Wenz, 1941:971.— Dolin, 1991:11 (synonomised *Gigantocypraea* Schilder, 1927). — Wilson and Clarkson, 2004:44.

Cypraeorbis (Zoila) Jousseaume. Schilder, 1926:378.

Umbilia (Gigantocypraea) Schilder, 1927:86 (type species, original designation, *Cypraea gigas* McCoy, 1867, Miocene, Victoria).

Zoila (Zoila) Jousseaume. Schilder, 1935:337.— Schilder, 1939:177.

Zoila (Gigantocypraea) Schilder. Schilder, 1935:337.— Schilder, 1939:177.— Wenz, 1941:971.

Cypraea (Zoila) Jousseaume. Wilson and McComb, 1967:469. — Wilson, 1993:192.

Type species. *Cypraea scottii* Broderip, 1832 (= *Cypraea friendii* Gray, 1831) by subsequent designation Jousseaume (1884b, p. 89), western and southern Australia.

Diagnosis. Shell small (35 mm) to very large (247 mm) in size, highly glazed, varying in shape, elongate-ovate or pyriform or globose, ventrally flattened. Spire whorls usually covered in callus, rarely protruding. Protoconch, where known, consisting of one to two whorls, the first whorl large, somewhat irregular in shape, deviated slightly from shell axis. Anterior and posterior canals deeply incised, usually short, but on some species produced and bounded by weak to prominent lateral flanges. Aperture narrow, sinuous with weakly to strongly developed short to elongate teeth not extending into aperture or onto fossula. Fossula weakly to strongly developed, broad, slightly to deeply concave and bounded anteriorly by a weak to strong terminal ridge; on some species with very weak sulcus parallel and immediately posterior to terminal ridge.

Time range. Late Paleocene/early Eocene–Recent.

Distribution. India (early Miocene), Indonesia (Pliocene–Pleistocene), Western Australia (late Eocene, Miocene–Recent), South Australia (Miocene, Recent), Victoria (late Oligocene–late Miocene, Recent), Tasmania (early Miocene), New Zealand (late Paleocene/early Eocene).

Remarks. Specimens of *Zoila itoigawa* Tomida, 1989 from the late Miocene of Japan are poorly preserved and have not been prepared sufficiently to enable generic assignment.

As I have recognised two groups of species, an eastern and a western group, it could be argued that these should be accorded taxonomic status if there are significant morphological differences to separate them, in which case *Gigantocypraea* could be used for the eastern group. However, I regard these groups as more geographic entities. There are some morphological differences, but I regard them as minor and not of sufficient importance to use as generic characters. Such variations in morphology are to be expected in species that have no pelagic larval stages.

Some species of the eastern group have considerably produced anterior and posterior canals — for example, *Zoila platypyga* (McCoy) and *Z. mulderi* (Tate) — but other species have canals similar to the living species of the western group — for example, *Z. glomerabilis* n. sp. is similar to *Z. venusta* (Sowerby, 1846) or *Z. gendinganensis* (Martin, 1899).

Columellar dentition varies considerably from species to species. In the living species, columellar dentition can vary from strong to weak even within the one species; for example,

Zoila friendi (Wilson and Clarkson, 2004, pp. 79–80). Fossil species of the western group all have prominent columellar dentition. In *Z. fodinata*, the columellar teeth are elongated to form short ridges. In the eastern group, columellar dentition is more highly variable. In *Z. platypyga*, the columellar dentition is in the form of strong, elongate ridges, whereas in *Z. mulderi* (Tate) (almost certainly ancestral to the former), the columellar dentition is more like that of the living species, as is the dentition of *Z. glomerabilis* sp. nov. and *Z. dolichorhyncha* sp. nov. In *Z. gigas*, there is no columellar dentition. I do not consider that columellar dentition can be used to provide a consistent taxonomic character to separate the eastern and western group of species of *Zoila* as implied by Wilson and Clarkson (2004, p. 49).

Fossular morphology also varies somewhat, though the basic pattern throughout all the species is the same — that is, broad, concave and bounded by the terminal ridge. Even within a species, fossular morphology can vary. Compare, for example, the fossulae of specimens of *Z. venusta* figured on plates 265–276 of Wilson and Clarkson (2004).

Zoila chathamensis (Cernohorsky, 1971)

Figures 1H, 5A, D-G, I-K

Bernaya chathamensis Cernohorsky, 1971, p. 117, fig. 13.

Description. Shell of small size for genus (36 mm), solid, somewhat globose to subpyriform, dorsal surface uniformly convex, ventral surface weakly convex, almost flat. Posterior canal narrow, barely projecting, deeply incised; anterior canal very short, deeply incised. Spire not visible. Outer lip with 14–16 teeth, columella lip with 12–18 teeth. Fossula well developed, smooth, broad, very slightly concave, slightly projecting, bounded by very weak terminal ridge.

Dimensions.

	L	W	H	LT	CT
Holotype AMNZ TM-1325	35.8	27.3	21.1	18.0	14.0
Figured specimen GNS TM8792	36.5	21.0	21.0	12.0	16.0

Type locality. Flowerpot Harbour, Pitt Island, Chatham Islands, New Zealand, Red Bluff Tuff, late Paleocene/early Eocene.

Occurrence and material. Pitt Island, New Zealand: Red Bluff Tuff, Flowerpot Harbour (holotype AMNZ TM-1325), (GNS GS12159, one specimen); Red Bluff Tuff, GS12173 Rocky side, Tarawhenua Peninsula (GNS TM8792, one specimen).

Remarks. Cernohorsky (1971) assigned his new species to the genus *Bernaya*, apparently not realising that the fossula of species assigned to that genus has a deep groove at the anterior end. His description of the fossula is quite accurate, but his figure does not show the morphology of the fossula very well, as it was not fully prepared. The holotype is refigured here, but the fossula is not very clear in the illustration (fig. 5I). Another specimen kindly provided by Dr Alan Beu has been more fully prepared and although the aperture is narrow, making photography, difficult the simple nature of the fossula can be seen (fig. 5J). The fossula is somewhat similar to that in *Z. viathomsoni* n. sp. and *Z. decipiens* (E.A. Smith, 1880), but is not as concave.

Although much smaller, the overall morphology of this species is somewhat similar to that of *Zoila friendii thersites* (Gaskoin, 1849). The fossula is relatively shorter and is not as deeply concave as that of the latter species, but is otherwise similar.

Zoila viathomsoni sp. nov.

Figures 1D, 2C, 5B–C, H, L

Description. Shell of small size for genus (19–28 mm in length), pyriform. Spire not visible on most specimens, projecting on one specimen. Posterior canal very short, slightly bent to left. Anterior canal very short, slightly deflected to right. Aperture slightly sinuous; outer lip with about 23–25 teeth present along entire lip; columella with about 23–26 teeth present along entire lip. Fossula well-developed, deep, elongate, projecting, bounded anteriorly by thickened ridge; very weak notch present in inner edge just posterior to anterior ridge; weak terminal ridge joining edge of fossula. First columellar tooth adjacent to terminal ridge, almost blocking shallow sulcus that extends into fossula parallel to terminal ridge.

Dimensions.

	L	W	H	LT	CT
Holotype WAM 72.296	24.0	16.0	12.5	25.0	26.0 undistorted
Paratype WAM 72.253	27.0	15.0 est.	14.0 est.	c24.0	24.0 distorted
Paratype P310193	28.0	15.0	13.0 est.	24.0	23.0 crushed laterally
Paratype P310194	17.0	11.7 fragment showing fossula			

est. = estimated

Type locality. PL3171 gravel scrape beside Thomson Highway, 23.5 km north of Highway 1, north of Walpole, Western Australia. Grid ref. Deep River (1:100 000 series) 743487. Pallinup Siltstone, Aldingan, Late Eocene.

Type material. Western Australian Museum: Holotype WAM 72.296, collected T.A. Darragh and G.W. Kendrick, 12–14 March 1969; paratype WAM 72.253, collected G.W. and W.E. Kendrick, 25 January 1969. Museum Victoria: Paratype P310193, collected T.A. Darragh & G.W. Kendrick, 12-14 March 1969.

Time range. Aldingan, Late Eocene.

Occurrence and material. Type locality only (one undistorted specimen, four complete distorted specimens, nine fragments).

Remarks. This is one of the two oldest true cowries recorded from Australia and occurs only in southwest Australia, associated with *Willungia ovulatella* (Tate) and *Semitrivia pompholugota* (Tate). Specimens from the type locality are preserved as silica replacements weathered out of the Pallinup

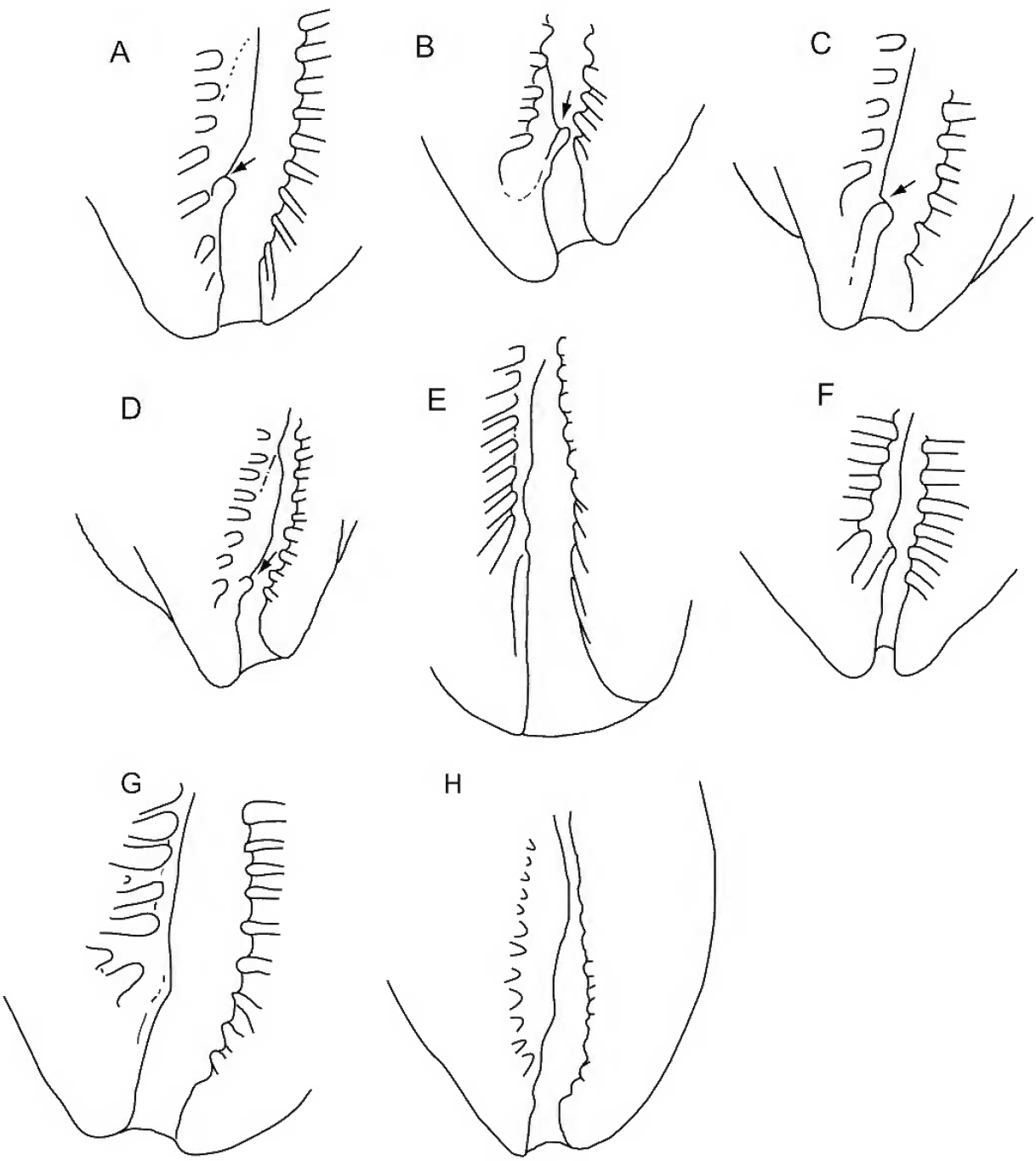

Figure 1. A, *Cypraeorbis medius* (Deshayes, 1835), × 5; B, *Cypraeorbis sphaeroides* (Conrad, 1848), × 5; C, *Cypraeorbis ventripotens* (Cossmann, 1903), × 5; D, *Cypraeorbis viathomsoni* sp. nov. WAM 72.296, × 5; E, *Zoila didymorhyncha* sp. nov. P302687, × 2.6; F, *Zoila campestris* sp. nov. WAM 89.437, × 2.6; G, *Zoila fodinata* sp. nov. WAM 89.637, × 3; H, *Zoila chathamensis* (Cernohorsky, 1971) GNSTM 87922, × 2.3. Arrows indicate the location of the notch.

Figure 2. Protoconchs. A, *Zoila platypyga* (McCoy, 1876), P308781, × 7; B, *Zoila gigas* (McCoy, 1867), P308792, × 3.6; C, *Zoila viathomsoni* sp. nov., WAM × 10.

Siltstone. The associated fauna comprises large numbers of siliceous sponges. The protoconch observed in cross-section (fig. 2C), is paucispiral and slightly deviated from the axis of the teleoconch, unlike the multispiral protoconchs of *Cypraeorbis* species. The general size and shape of the shell resembles that of *Cypraeorbis medius*, *C. bartonensis* and *C. ventripotens*; however, the fossula (fig. 5L) is not the same as that present in these species. The fossula is very wide and prominent, projecting into the aperture. It is more elongate than that of these three species, does not have a prominent notch and the anterior border is not thickened. In general shape and concavity, it resembles those in *Zoila friendii* and *Z. decipiens*. *Zoila viathomsoni* bears a close resemblance to *Z. chathamensis* (Cernohorsky), late Paleocene to early Eocene, Chatham Islands, New Zealand, but it is not as tumid, has much finer and more numerous apertural teeth, the posterior labral border of the posterior canal is more produced posteriorly and it is only about two-thirds the size. Given the similarities, *Z. chathamensis* is a possible ancestor of *Z. viathomsoni* sp. nov.; *Z. chathamensis* is the earliest known representative of the genus.

Zoila viathomsoni bears some resemblance in size and shape to *Lyncina (Austrocypraea) onkastoma* Yates, 2009, recorded from the early Oligocene of South Australia, but lacks the well-defined anterior rostrum of *L. (A.) onkastoma*, as well as the prominent notch on the fossula.

Etymology. Latin via road.

Zoila didymorhyncha sp. nov.

Figures 1E, 6A–E, I

Description. Shell solid, small for genus, elongate, subfusiform; base relatively flat, but rounded on either side of aperture. Spire not visible. Posterior canal long, with rounded sides, sunk into massive rounded posterior rostrum formed by extensions of inner and outer lips. Anterior canal long, with rounded sides, sunk into a thick, rather flat rostrum. Aperture somewhat sinuous; outer lip with 10–24 well-developed teeth extending along entire lip; teeth completely obsolete on one specimen. Columella lip with 3–26 well-developed teeth extending along entire lip on most specimens; teeth obsolete on one specimen. Fossula moderately developed, very shallow, bounded anteriorly by a small, weak, terminal ridge.

Dimensions.

	L	W	H	LT	CT
Holotype P302687	62	31	25	24	26
Paratype P302685	80	32	27	10	3
P302686	64+	32	26	22+	25 anterior canal broken

Type locality. PL3022 cliff section at Addiscot Beach, beds Bl09–l07, southwest of small gully, clay overlying Demons Bluff Formation, Victoria. AMG Torquay BT6l9490. Jan Juc Formation. Early Janjukian.

Type material. Holotype P302687, collected T.A. Darragh, 4 December 1985; paratype P302685, collected T.A. Darragh 8 May 1990.

Time range. Early Janjukian, Late Oligocene.

Occurrence and material. PL3022 Addiscott Beach (three specimens).

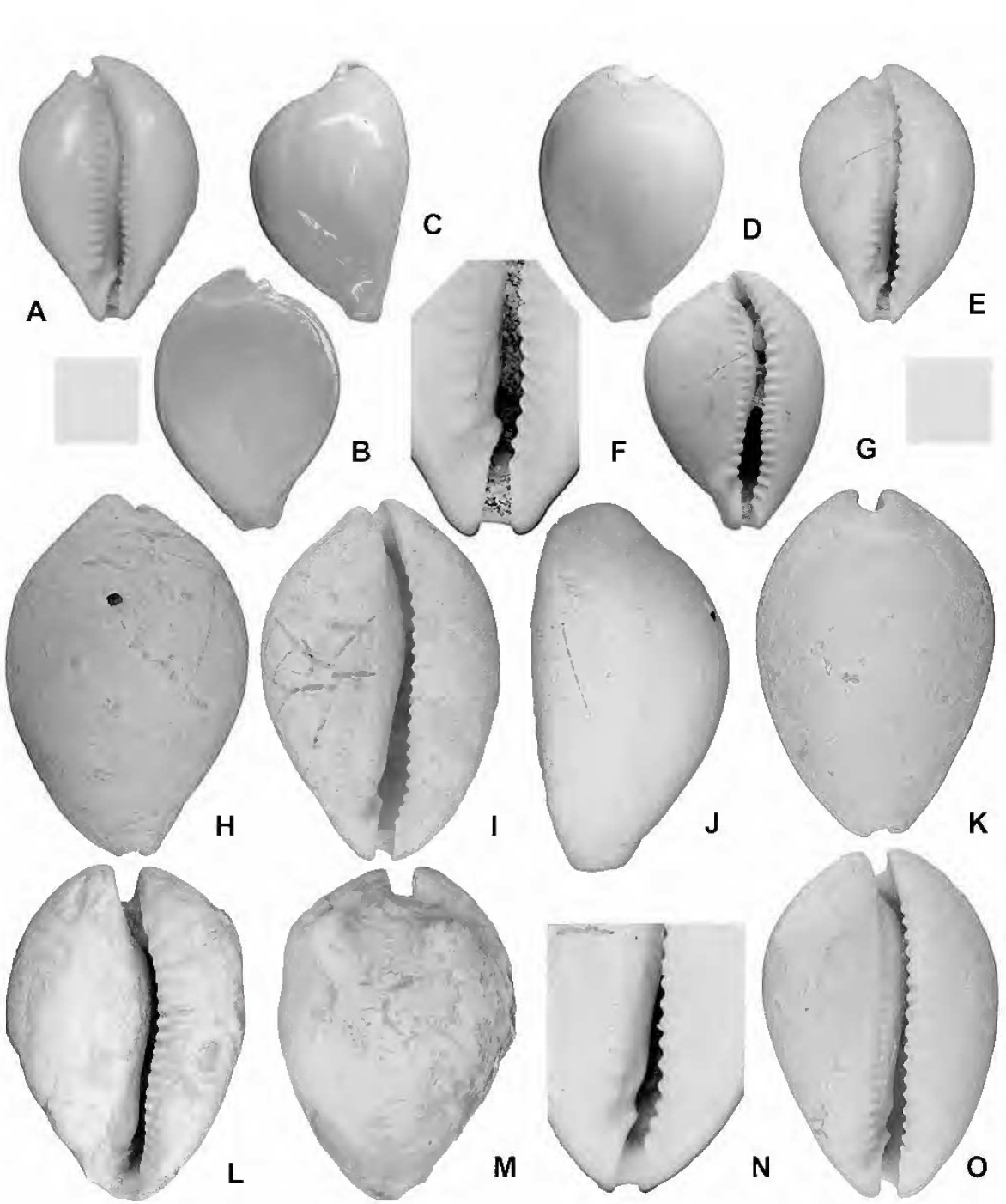

Figure 3. A–G, *Cypraeorbis ventripotens* Moodys Branch Formation, late Eocene, Town Creek, Jackson, Mississippi, United States of America; A–C, × 2; F, × 4; D–E, G, × 2; H–J, N, *Cypraeorbis arlettae* MNHN, Chipola Formation, Burdigalian, early Miocene, Farley Creek, Calhoun County, Florida, USA; K, O, *Cypraeorbis wilcoxi* MNHN, Chipola Formation, Burdigalian, early Miocene, Farley Creek, Calhoun County, Florida, United States of America; L–M, *Barycypraea zietsmani* Liltved and Le Roux, 1988, P31664, Alexandria Formation, late Neogene, Eastern Cape, South Africa, × 1.

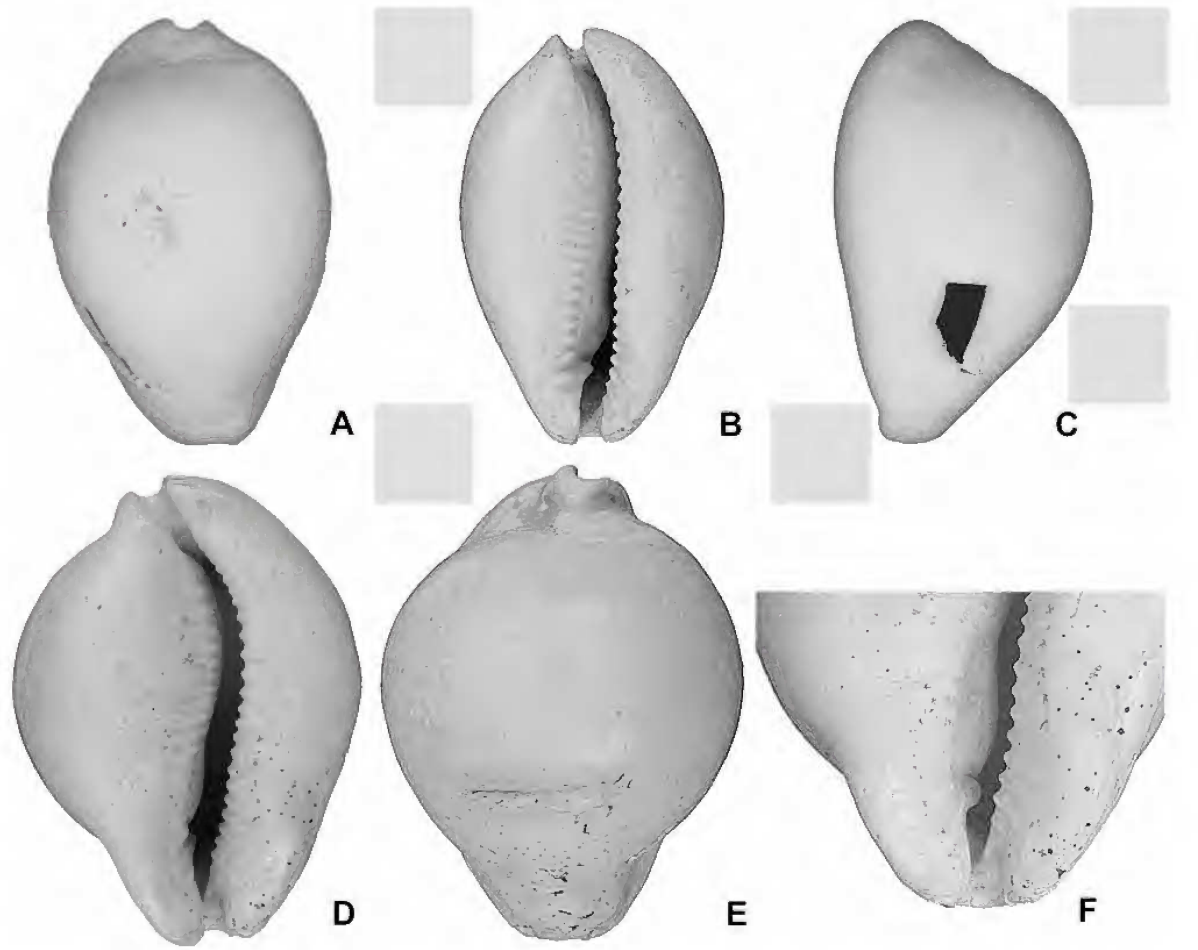

Figure 4. A–F, *Cypraeorbis medius* MNHN, Bartonian, late Eocene, Bois du Rois, Auvers sur Oise, France; A–C, D–E, × 1.5; F, × 2.

Remarks. The small size and the massive development of the anterior and posterior rostra separate this species from all others in the genus. In morphology, it comes closest to *Zoila mulderi* (Tate), but it has a massive anterior rostrum lacking in *Z. mulderi* and the posterior rostrum is not notched as it is in *Z. mulderi*.

Etymology. Greek, didymos, double; rhynchos, snout.

Zoila glomerabilis sp. nov.

Figures 6F–H, 7A–F

Description. Shell of large size for genus, solid, globosely pyriform, abruptly contracted anteriorly to short, narrow anterior canal. Spire projecting slightly, almost entirely enveloped by last whorl, covered with thick callus. Posterior canal short, deeply incised, reflexed to the left. Anterior canal deeply incised, with rounded sides, reflexed dorsally, supported laterally by very short, narrow flanges. Aperture sinuous, slightly widened and sloping steeply inwards before anterior canal. Outer lip with 28–36 teeth extending along entire lip; inner lip with 15–32 teeth extending along entire lip on most specimens; weaker posteriorly on some specimens and on few specimens extending only along half of lip. Fossula well developed, broad, relatively deeply depressed, bounded anteriorly by weak terminal ridge.

Dimensions.

	L	W	H	LT	CT
Holotype P14515	96	59	52	35	30
Paratype P308740	85	52	40	35	26
Paratype P315526	80	50	42	33	13

Type locality. Lower beds of section south of Fishermen's Steps, Bird Rock Cliffs, Torquay, Victoria. Jan Juc Formation.

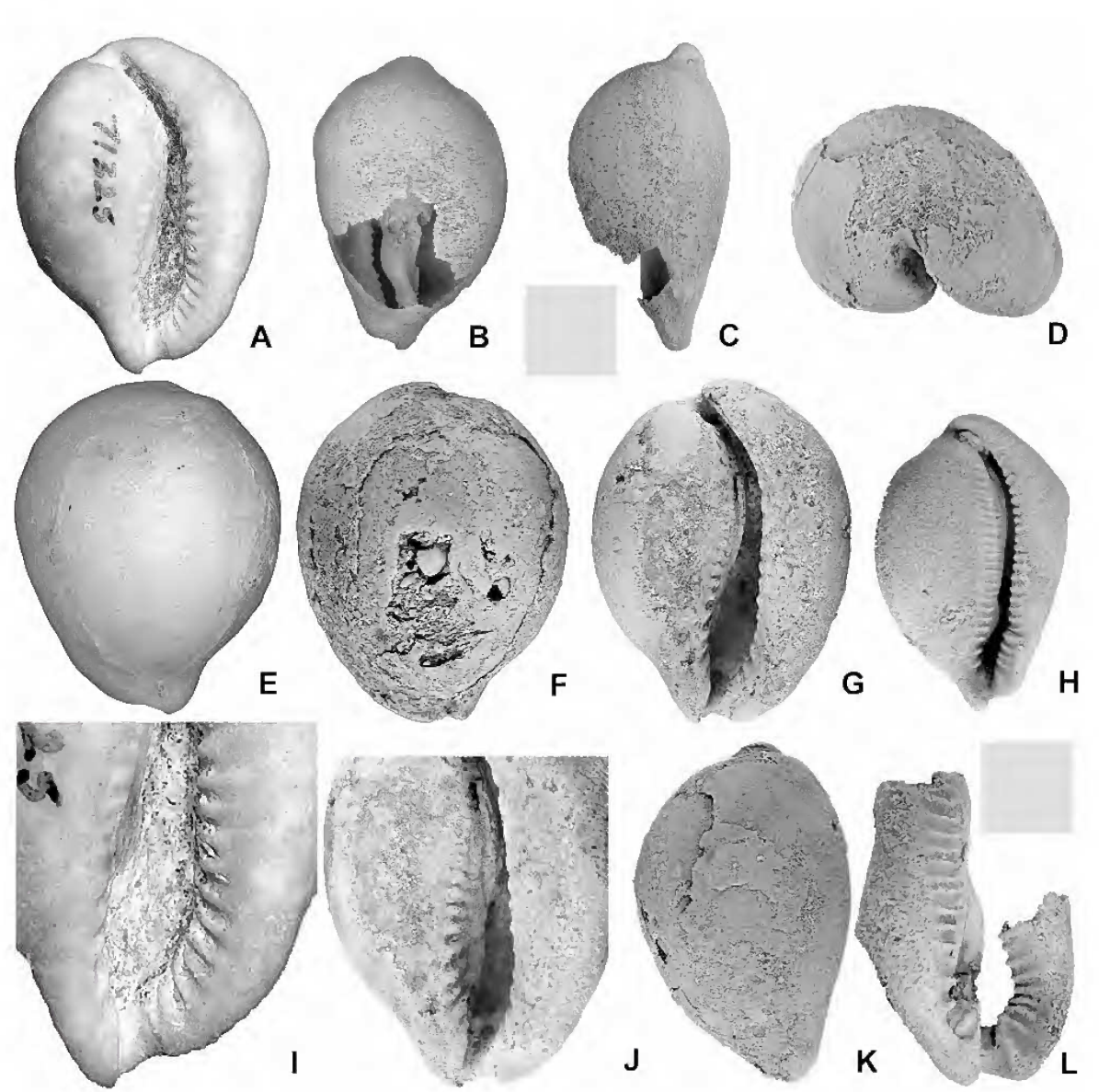

Figure 5. A, D–G, I–K, *Zoila chathamensis*; A, E, I, holotype, AIM 71325, Flower Pot Harbour, Chatham Islands; A, E, × 1.5; I, × 2; D, F–G, J–K, GNS TM8792, Taruwhenua Peninsula, Chatham Islands; D, F–G, K, × 1.5; J, × 2; B–C, H, L, *Z. viathomsoni*; B–C, H, holotype, WAM 72.296, Thomson Highway, Western Australia; L, fossula, P310194, Thomson Highway, × 3.

Type material. Holotype P14515, F.A. Cudmore collection; paratype P308740, presented S. F. Colliver, 16 January 1962; paratype P315526, presented C. Goudey, 2009.

Time range. Janjukian, Late Oligocene–Longfordian, Early Miocene.

Occurrence and material. Janjukian: Jan Juc Formation. At sea level, Bird Rock, Torquay (P304422, one specimen); Half Moon Bay, Torquay (P315526, one specimen); Torquay (P308706, P304432, P304423, seven specimens); Geological Survey of Victoria locality Ad22, Bird Rock, Torquay (P308717, one specimen).

Longfordian: Fishing Point Marl. 'Picnic bed', Horden Vale (P308741-2, two specimens).

Remarks. This species is very similar in morphology to

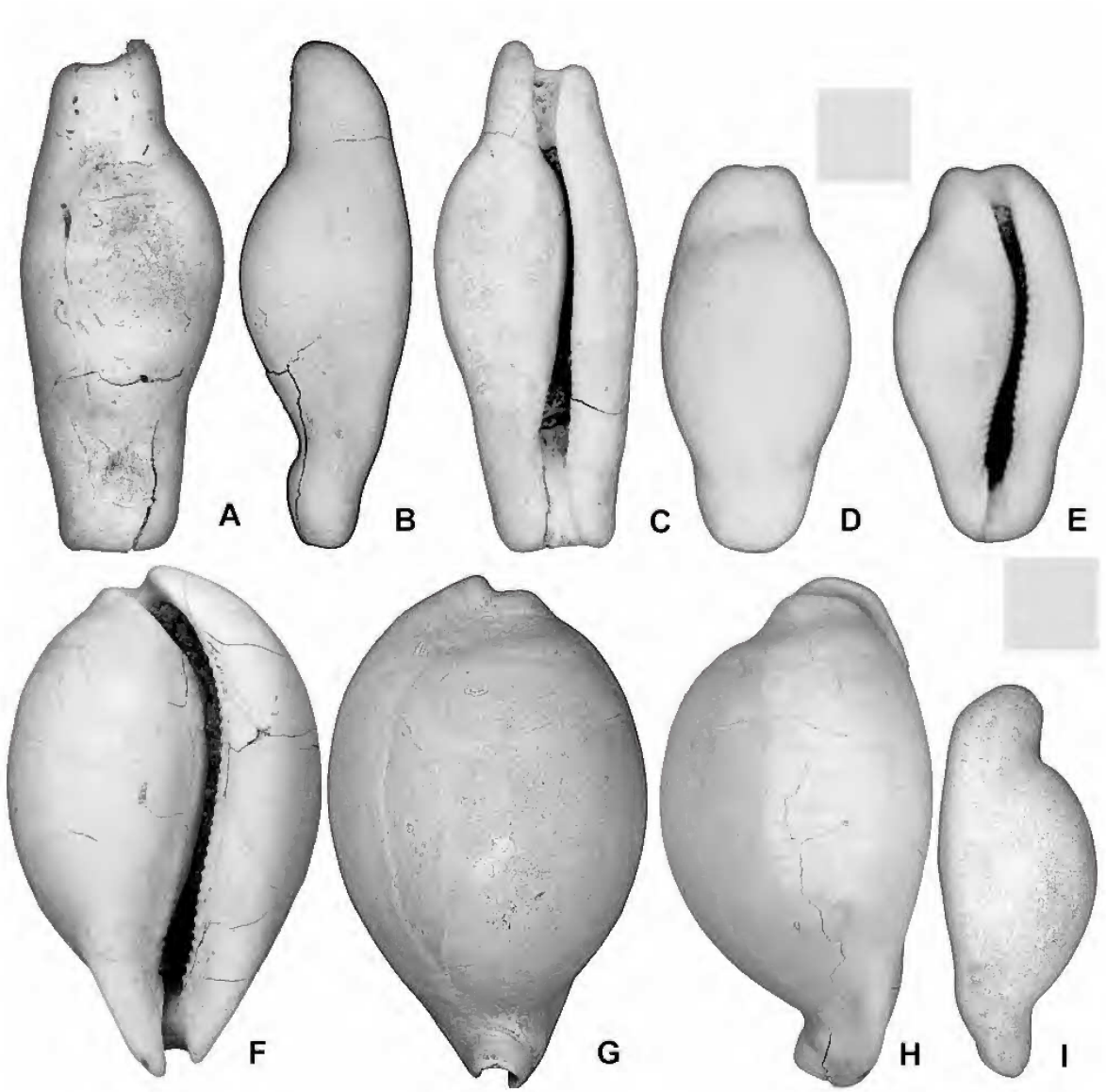

Figure 6. A–E, I, *Zoila didymorhyncha*; A–C, paratype, P302685, PL3022, × 1; D–E, I, holotype, P302687, PL 3022, × 1; F–H, *Z. glomerabilis*, paratype, P315526, Half Moon Bay, Torquay, × 1.

Z. dolichorhyncha sp. nov. but differs in that it is more globose, has a shorter anterior canal and tapers more abruptly towards the anterior. *Zoila glomerabilis* bears some resemblance to *Z. venusta* (Sowerby), Recent, Western Australia, but is more globose and has a prominent anterior canal lacking in *Z. venusta*. The fossula is very similar to that in *Z. venusta*, but not quite as elongate.

Etymology. Latin, glomerabilis, round.

Zoila dolichorhyncha sp. nov.

Figures 8A–F, 9C–E

Description. Shell of large size for genus, solid, pyriform, somewhat humped posteriorly and tapering anteriorly, of six teleoconch whorls. Spire projecting slightly, almost enveloped by last whorl, covered with thick callus. Protoconch of one smooth whorl, not differentiated from teleoconch whorls,

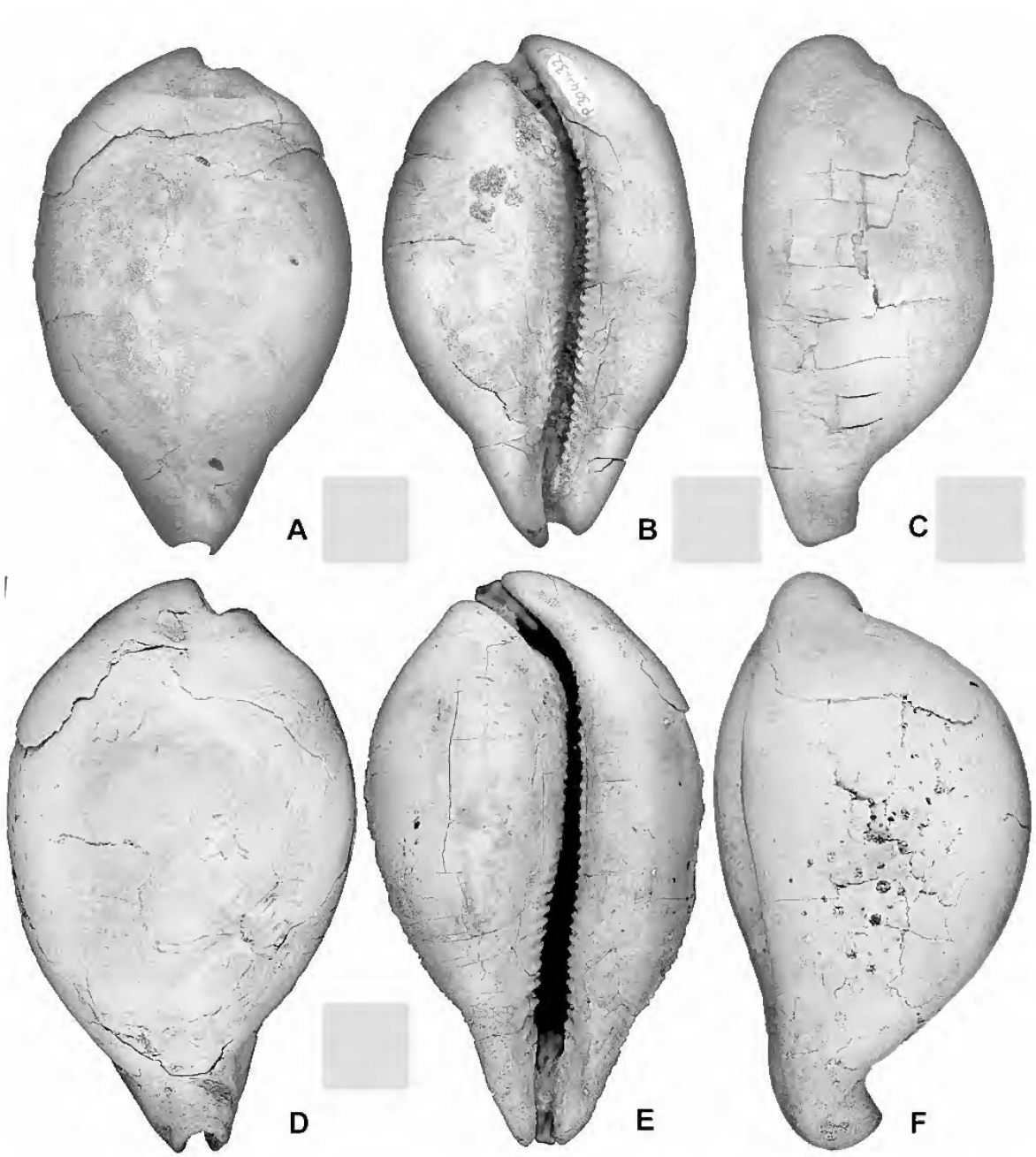

Figure 7. A–F, *Zoila glomerabilis*; A–C, paratype, P308740, Torquay, × 1; D–F, holotype, P14515, Bird Rock cliffs, Torquay, × 1.

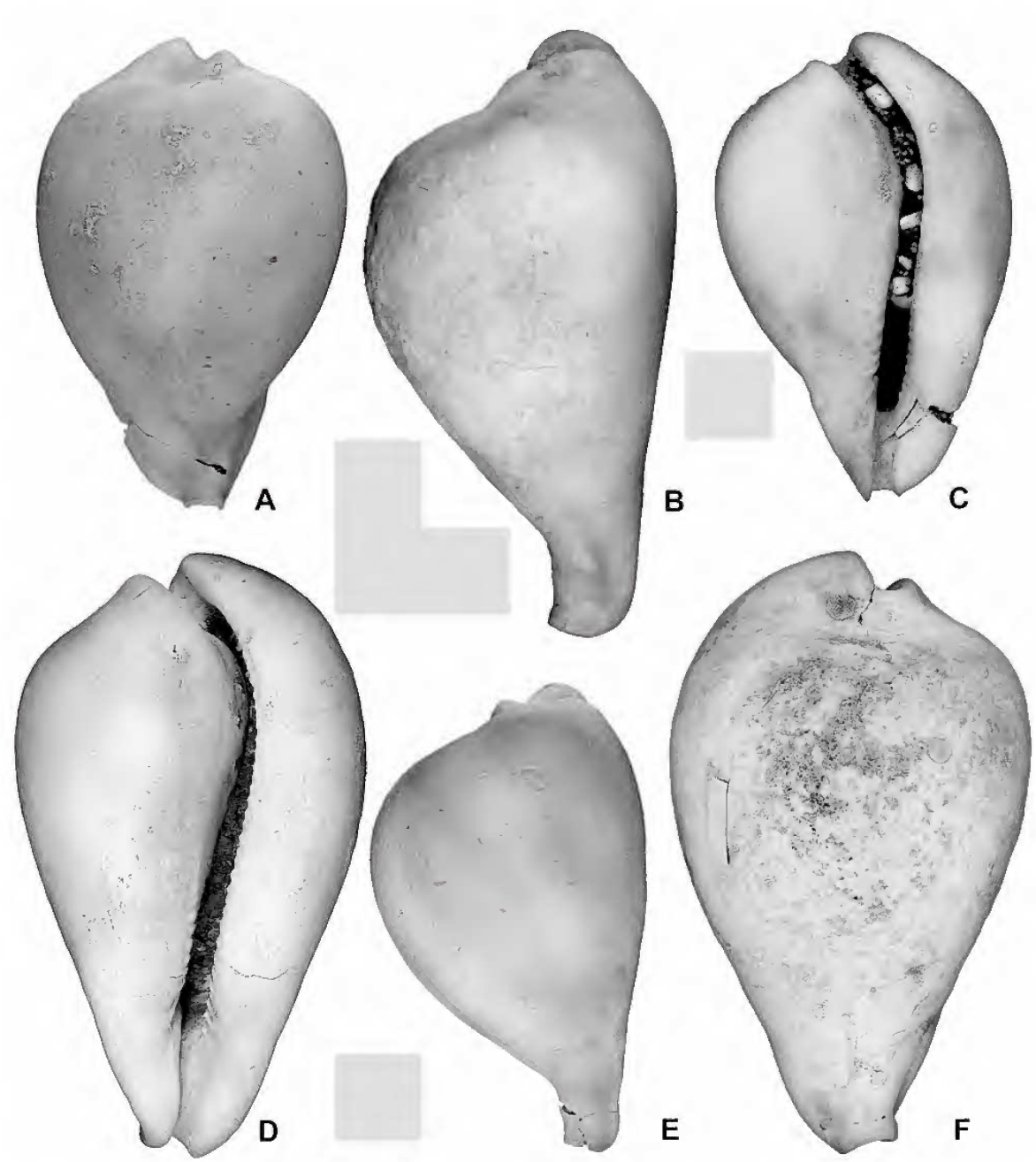

Figure 8. A–F, *Zoila dolichorhyncha*; A, C, E, paratype, P304418, PL3028, × 1; B, D, F, holotype, P14514, PL 3028, × 1.

coiled with the axis of the shell. Posterior canal short, deeply incised, reflexed to left. Anterior canal deeply incised, with rounded sides, reflexed dorsally, supported laterally by short, narrow flanges. Aperture sinuous, slightly widened and sloping steeply inwards before anterior canal; outer lip with 23–33 teeth extending along entire lip, on some specimens becoming very weak posteriorly; inner lip with 3–11 teeth (generally fewer than 10) present on anterior third of lip. Fossula well developed, broad, relatively deeply depressed, bounded anteriorly by weak terminal ridge.

Dimensions.

	L	W	H	LT	CT
Holotype P14514	101	60	52	33	10
Paratype P304417	81	47	42	26	7
Paratype P304418	79	51	45	24	8

Type locality. Lower bed, Table Cape, Wynyard, Tasmania, (i.e. PL3028 lower bed in cliff between Fossil Bluff and 1.5 km northwest towards Table Cape, Wynyard, Tasmania, Table Cape 930630). Freestone Cove Sandstone, Early Miocene, early Longfordian.

Type material. Holotype P14514, purchased R.N. Atkinson, 8 May 1911; paratypes P304417-8, purchased R.N. Atkinson, 15 January 1910.

Time range. Longfordian, Early Miocene

Occurrence and material. Table Cape (P2644, P14618, P2766-2770, P14595-6, P304417, P304449-50, 11 specimens); *Crassatella* bed, Fossil Bluff (P304440, one specimen); lower bed, Table Cape (P308708, P304431, P304433, seven specimens).

Remarks. This species has been mistaken for *Zoila platypyga* (McCoy) and recorded as such in lists of fossils from Table Cape published by Johnston (1888, p. 262) and Pritchard (1896, p. 106). It probably evolved from *Z. glomerabilis* sp. nov., from which it differs by being pyriform with a tapering anterior rather than being globose. *Zoila glomerabilis* has a uniformly rounded dorsum, whereas *Z. dolichorhyncha* sp. nov. has a dorsum humped posteriorly.

Etymology. Greek, dolichos, long; rhynchos, snout.

Zoila mulderi (Tate, 1892)

Figures 9A–B, 10A–F

Cypraea mulderi Tate, 1892, pl. 9, fig. 2.— Tate, 1893, p. 316 (description).

Gistortia (Palliocypraea) mulderi (Tate).— Vredenburg, 1927, p. 60.

Zoila (Zoila) mulderi (Tate).— Schilder, 1935, p. 337.

Zoila (Gigantocypraea) mulderi (Tate).— Wilson and Clarkson, 2004:52, pl. 56.

Description. Shell solid, of medium to large size for genus, subglobose, covered with glaze. Spire scarcely visible, covered with thick callus. Posterior canal wide, sides rounded, deeply notched dorsally, sides extended posteriorly into prominent thick flanges extending from base. Anterior canal deeply incised, sides rounded, reflexed dorsally, supported by very thick lateral flanges extending from base. Aperture somewhat sinuous, narrow; outer lip with 24–32 teeth, markedly decreasing in strength at posterior two-thirds. Columella with 9–29 weak, short teeth, present on anterior two-thirds. Fossula weakly depressed, subcircular, bounded anteriorly by weak terminal ridge. Dorsum coarsely dimpled on some specimens.

Dimensions.

	L	W	H	LT	CT
Holotype SAM T822	102	64	49	29	8
Figured specimen P13374	96	60	45	32	11 topotype
Figured specimen P3044471	106	63	49	23+	14 Curlewis

Type locality. 'In a well sinking at Belmont'. A note by Mulder, dated 1891, with a photograph of the specimen sent to Professor Tate (i.e. the holotype), states that only two specimens were known, one in Mulder's possession (i.e. P13374) and the other sent to Tate. They were 'taken from the bottom of a shaft about 60 feet below the surface. The shaft was sunk at Belmont near Geelong'. The shaft was sunk in about 1891 in an effort to find fire clay in a paddock close to the junction of the Colac Road (now Princess Highway) and the Germantown (now Grovedale) Road (now Corio Street), probably in allotment 9, Parish of Barrabool. The site was described by Mulder (1897, p. 23).

Type material. Holotype SAM T822, R. Tate collection.

Figured specimen P13374, collected J.F. Mulder 1891, purchased 1921; figured specimen P3044471, collected F.A. Cudmore, 21 April 1940.

Time range. Longfordian–Batesfordian, Early Miocene.

Occurrence and material. Longfordian. Fishing Point Marl: PL3035 southeast of Fischers Point (P308770, one fragment).

Batesfordian. Fyansford Formation: PL3040 Belmont Shaft (P13374, one specimen). Curlewis (P304416, P304447, P308743, four specimens and three fragments).

Gellibrand Formation: PL3048 Bornong Road cutting (P304421-2, P308767, one specimen and two fragments); PL3163 Williams Road cutting (P310103, one fragment of anterior).

Horizon unknown. Fishing Point Marl? 'Cape Otway' (probably Aire River) (P302701, one specimen).

Fishing Point Marl: Fishing Point (P308769, one fragment).

Remarks. The Bornong cutting specimens have the general shape of specimens from Belmont and Curlewis, but have some characters intermediate with *Zoila platypyga* (McCoy) in that the teeth are more strongly developed. The labral teeth extend along the entire lip and the columellar teeth are strongly developed ridges extending along the entire columella as in *Z. platypyga*. This suggests that *Z. mulderi* is ancestral to *Z. platypyga*. The specimen labelled Cape Otway probably came from the upper part of the Fishing Point Marl (Batesfordian) outcropping in the cliffs along the Aire River at Horden Vale.

Figure 9. A–B, *Zoila mulderi* holotype, SAM T822, Belmont, × 1; C–E, *Z. dolichorhyncha*, paratype, P304417, PL 3028, × 1.

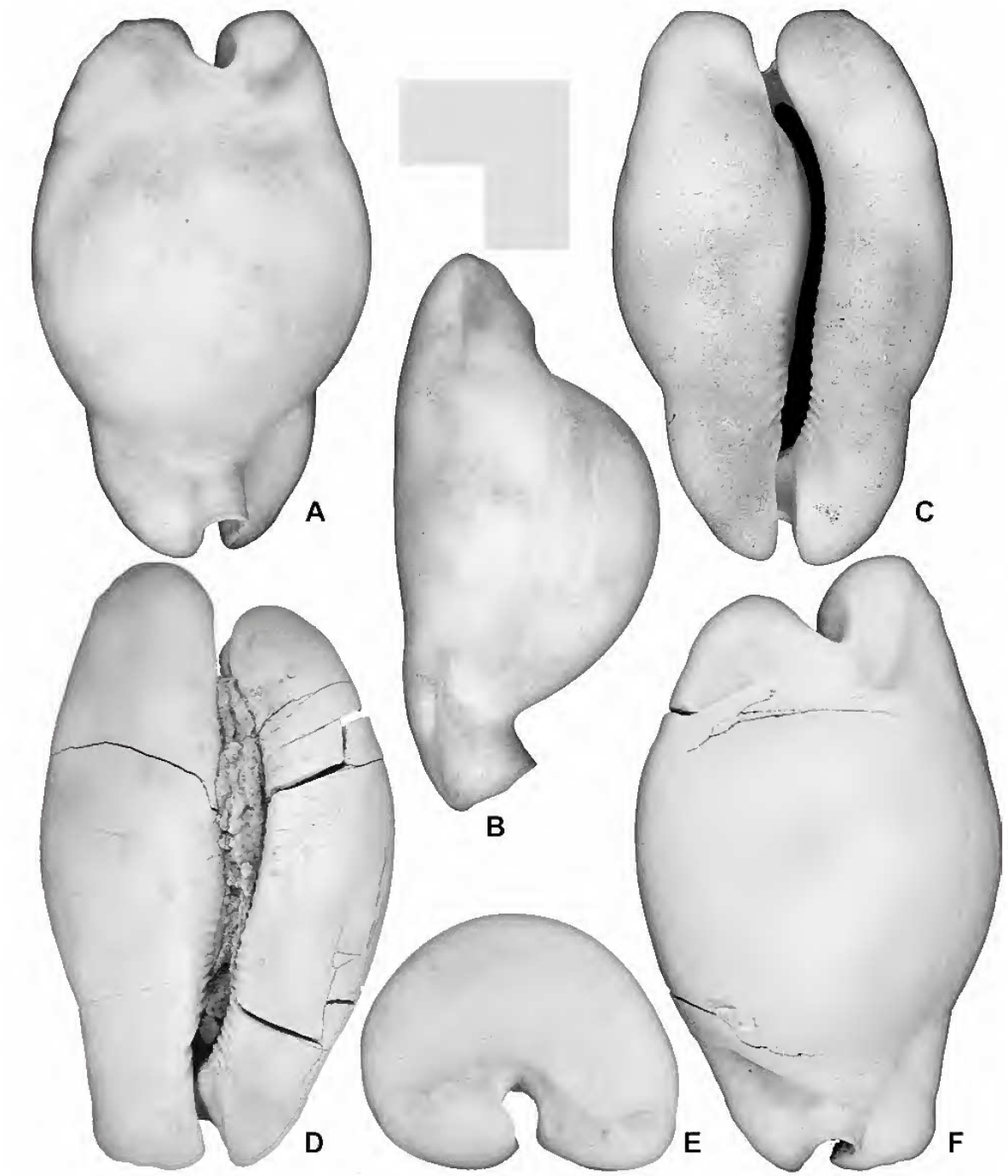

Figure 10. A–F, *Zoila mulderi*; A–C, E, P13374, Belmont, × 1; D, F, P304416, Curlewis, × 1.

Zoila platypyga (McCoy, 1876)

Figures 2A, 11A–H, 12A–G, 13A–C

Cypraea (Aricia) platypyga McCoy, 1876, p. 39, fig. 1-1c.
Cypraea (Aricia) consobrina McCoy, 1877, p. 36, pl. 49, fig. 2.
Cypraea toxorhyncha Tate, 1890, p. 210.— Tate, 1892, p. 5, fig. 6; pl. 6, fig. 5.
Cypraea platypyga McCoy.— Tate, 1890, p. 211.
Cypraea (Erosaria) platypyga McCoy.— Harris, 1897, p. 209.
Gisortia platypyga (McCoy).— Vredenburg, 1927, p. 43.
Gisortia consobrina (McCoy).— Vredenburg, 1927, p. 43.
Zoila (Zoila) platypyga platypyga (McCoy). — Schilder, 1935, p. 338.
Zoila (Zoila) platypyga simplicior Schilder, 1935, p. 338.
Zoila (Zoila) consobrina (McCoy).— Schilder, 1935, p. 338.
Zoila (Zoila) toxorhyncha (Tate).— Schilder, 1935, p. 338.
Zoila platygyra [*sic*] (McCoy). — Wilson and Clarkson, 2004:51, pl. 52, pl 53 (*toxorhyncha*) form.
Zoila consobrina (McCoy). — Wilson and Clarkson, 2004:51, pl. 54.

Description. Shell of five to six whorls, solid, of medium size for genus, globose to subpyriform, last whorl covered with glaze, enveloping the previous whorls, somewhat humped posteriorly with posterior dorsal slope steeper than anterior; smooth dorsal surface. Spire slightly projecting, of 4–5 whorls, covered with thick callus on most specimens. Protoconch smooth, of one whorl merging imperceptibly with teleoconch whorls; beginning of protoconch slightly immersed. Posterior canal with rounded sides, wide, notched, projecting posteriorly on most specimens with prominent solid lateral projections, longer on columellar side. Anterior canal subcylindrical, narrow, deeply incised, reflexed dorsally and supported by thick lateral flanges on most specimens; on large specimens canal considerably extended. Aperture narrow, very slightly curved, slightly wider and steeply sloping inwards at anterior end before anterior canal; outer lip with 24–33 well-developed teeth extending along entire lip. Columella with 24–33 strongly developed ridges, extending along entire columella, bifurcating on some specimens, not extending onto fossula. Fossula well developed, concave, broad and spoon-shaped, bounded anteriorly by well-developed single terminal ridge.

Dimensions.

	L	W	H	LT	CT
Holotype P12137	77	49	42	24	27
P12134	67	43	37	30	28 holotype of *consobrina*
T823	94	47	42	28	26 holotype of *toxorhyncha*
Figured specimen P304414	100	54	51	33	33
Figured specimen P304415	82	50	41	30	30
Figured specimen P14594	100	53	51	33	26

Type locality. 'Tertiary clays of shore near foot of Mount Eliza'.

Type material. Holotype P12137, collected Geological Survey of Victoria. Holotype of *Cypraea (Aricia) consobrina* P12134, Moorabool River. Holotype of *Cypraea toxorhyncha* Tate, 1890, SAM T832, Muddy Creek, Ralph Tate collection. Holotype of *Zoila (Z.) platypyga simplicior* Schilder, 1935, BM(NH), Muddy Creek, E.O. Teale collection (specimen missing). Figured specimen P304414, F.A. Cudmore collection, collected 1941. Figured specimen P304415, presented Mr J. T. Cunningham, 22 February 1966. Figured specimen P14954, collected F.A. Cudmore, February 1932.

Time range. Balcombian–Bairnsdalian, Middle Miocene.

Occurrence and material. Balcombian. Muddy Creek Formation: Muddy Creek (P14639, P61587, P304426, P308692-4, P308696, P308748, P308798, P308796, 21 specimens); PL3082 Clifton Bank (P58641, P304419, P304434, P304446, P308691, P308695, P308697, 16 specimens).

Gellibrand Formation: Gellibrand River (P304424, P304448, P308734, four specimens); northwest of Princetown (P304441, one specimen); Princetown (P5347, one specimen); PL3060 dam on lot 393 (P304429, one specimen); 4 km north of Port Campbell (P304439, one specimen); between Pt. Ronald and Gibsons Beach (P304444, one specimen); Cowley Creek (P304438, one specimen); dam at Clyne's house (P308698, one specimen); north of Port Campbell (P308699, one specimen); Curdies (P59228, one specimen); PL3068 southwest end of Gibson Beach (P304443, one specimen).

Fyansford Formation: PL3078 Fossil Beach (P304427-8, P304437, P304415, ten specimens); Balcombe Bay (P308751-3, three specimens); Schnapper Point (P308755, two specimens); Braeside Tunnel (P30445, one specimen); Campbells Point (P304436, one specimen); PL3069 Red Bluff, Shelford (P304435, one specimen); Shelford (P304420, one specimen); Overburden, Batesford Limestone Quarry (P308811, P309021-3, P310316, P310313, six specimens).

Cadell Marl: PL3084 south of Morgan, South Australia (P304430, one specimen).

Bairnsdalian

Fyansford Formation: Grices Creek (P14594, P304425, five specimens); PL3103 downstream Grices Creek (P308754, one specimen); Grices Creek, middle beds (P304414, one specimen); PL3100 Murgheboluc 4A (P308735, one specimen).

Remarks. The holotype of *Cypraea consobrina* McCoy is a slightly immature, water-worn specimen found in the Moorabool River near Geelong, washed out of the Fyansford Formation. The posterior and anterior canals are not so highly callused, even when allowing for wear, as typical specimens of *Z. platypyga*. However, these forms intergrade and it is synonymised with the latter.

The holotype of *Cypreaea toxorhyncha* Tate is a large specimen, with the extensions of the posterior canal very well developed. The anterior canal is very long and reflexed dorsally. Similar specimens are associated with and intergrade with typical *Z. platypyga* specimens in the Muddy Creek Formation and the Fyansford Formation. This name is also synonymised with *Zoila platypyga*. The holotype of *Zoila (Zoila) platypyga simplicior* Schilder, 1935, said to be in the Teale collection, Natural History Museum, London, cannot be located. Schilder indicated that it came from Muddy Creek and that it differed from *Z. platypyga* sensu stricto by having less produced and less rounded extremities,

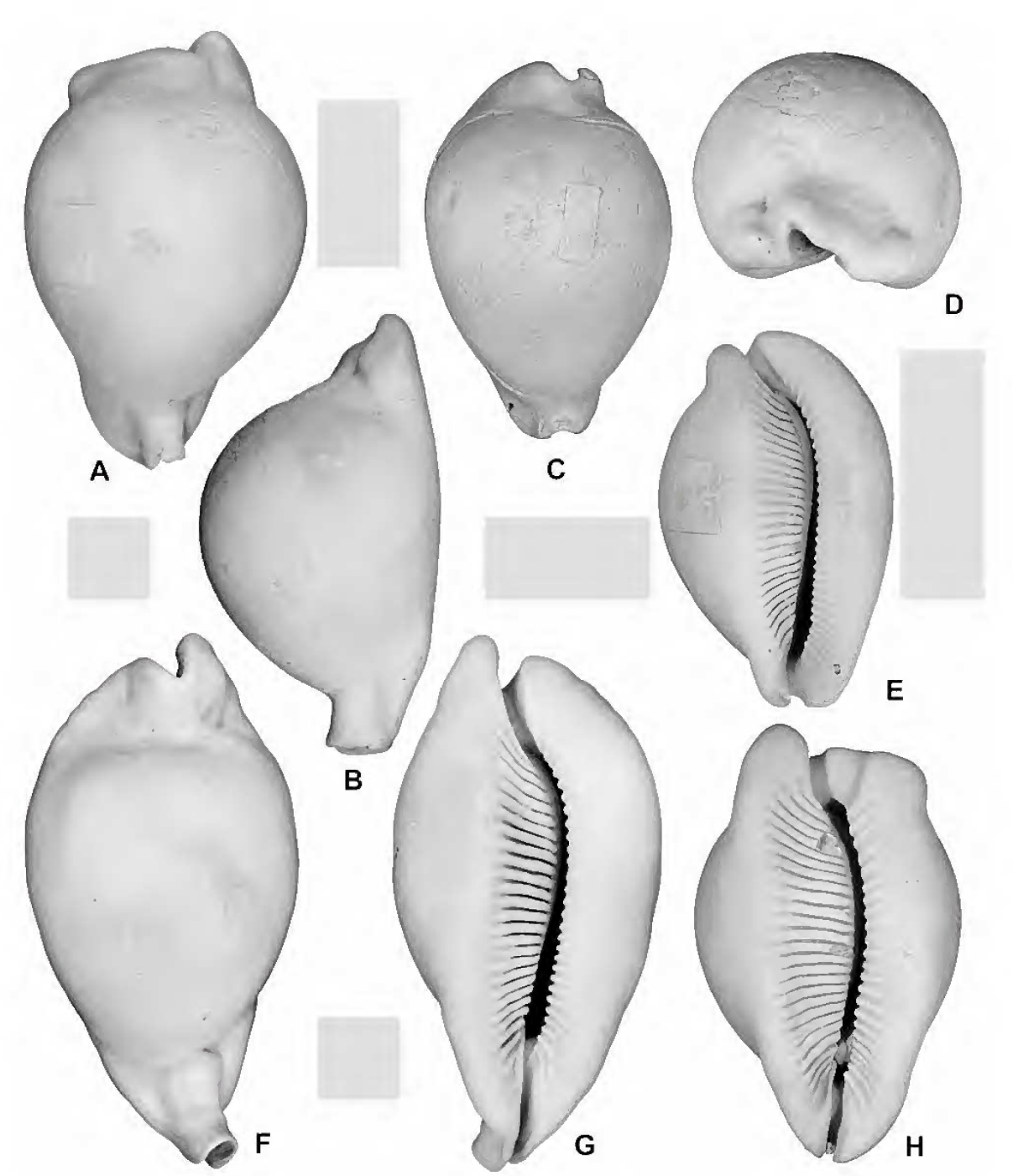

Figure 11. A–H, *Zoila platypyga*; A–B, D, H, holotype, P12137, Mount Eliza, × 1; C, E, holotype of *Cypraea consobrina* McCoy, P12134, Mooroobool River, × 1; F–G, holotype of *Cypraea toxorhyncha* Tate, SAM T 823, Muddy Creek, × 1.

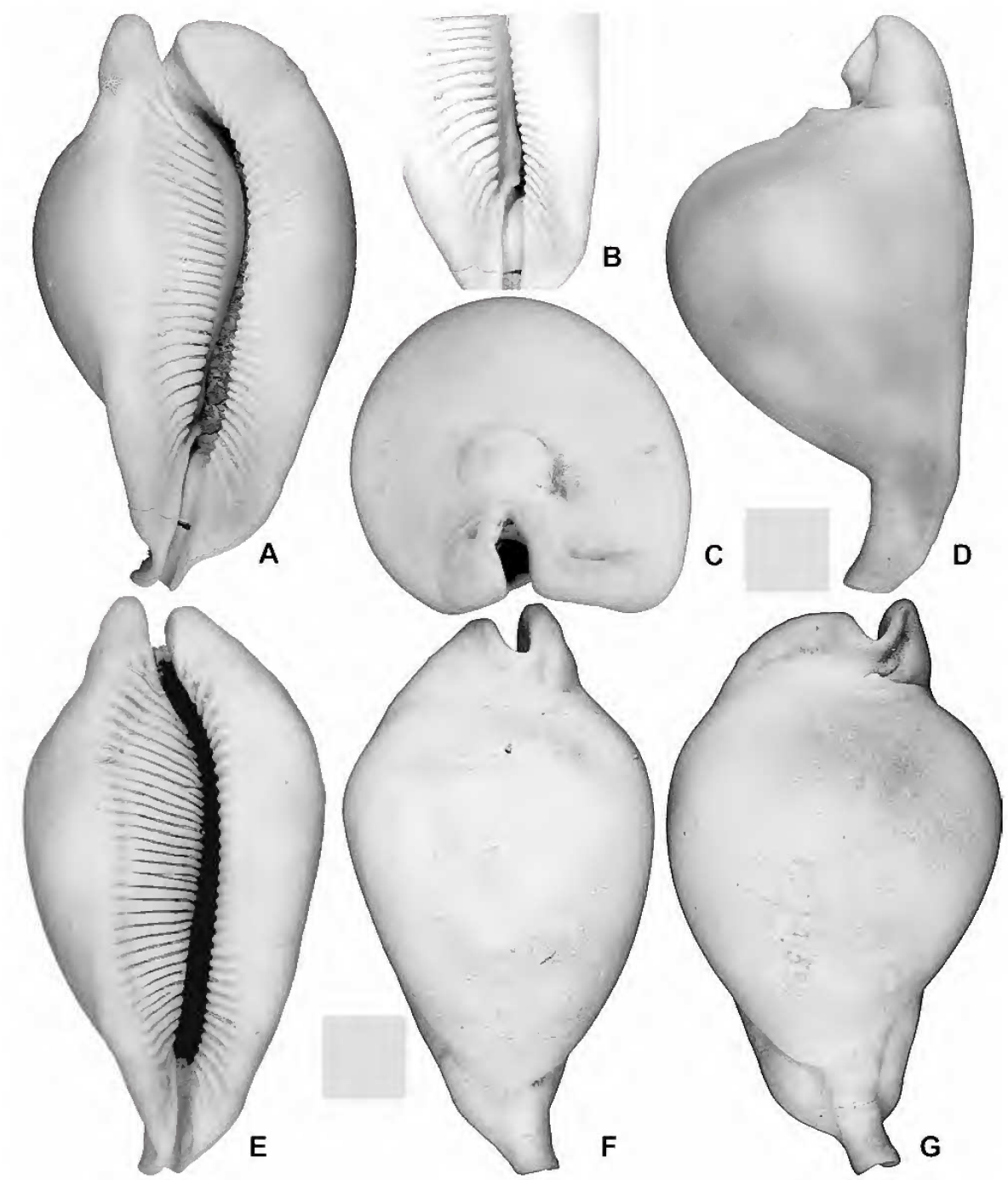

Figure 12. A–H, *Zoila platypyga*; A–D, G, P14594, Grices Creek, × 1; E–F, P304414, Grices Creek, × 1.

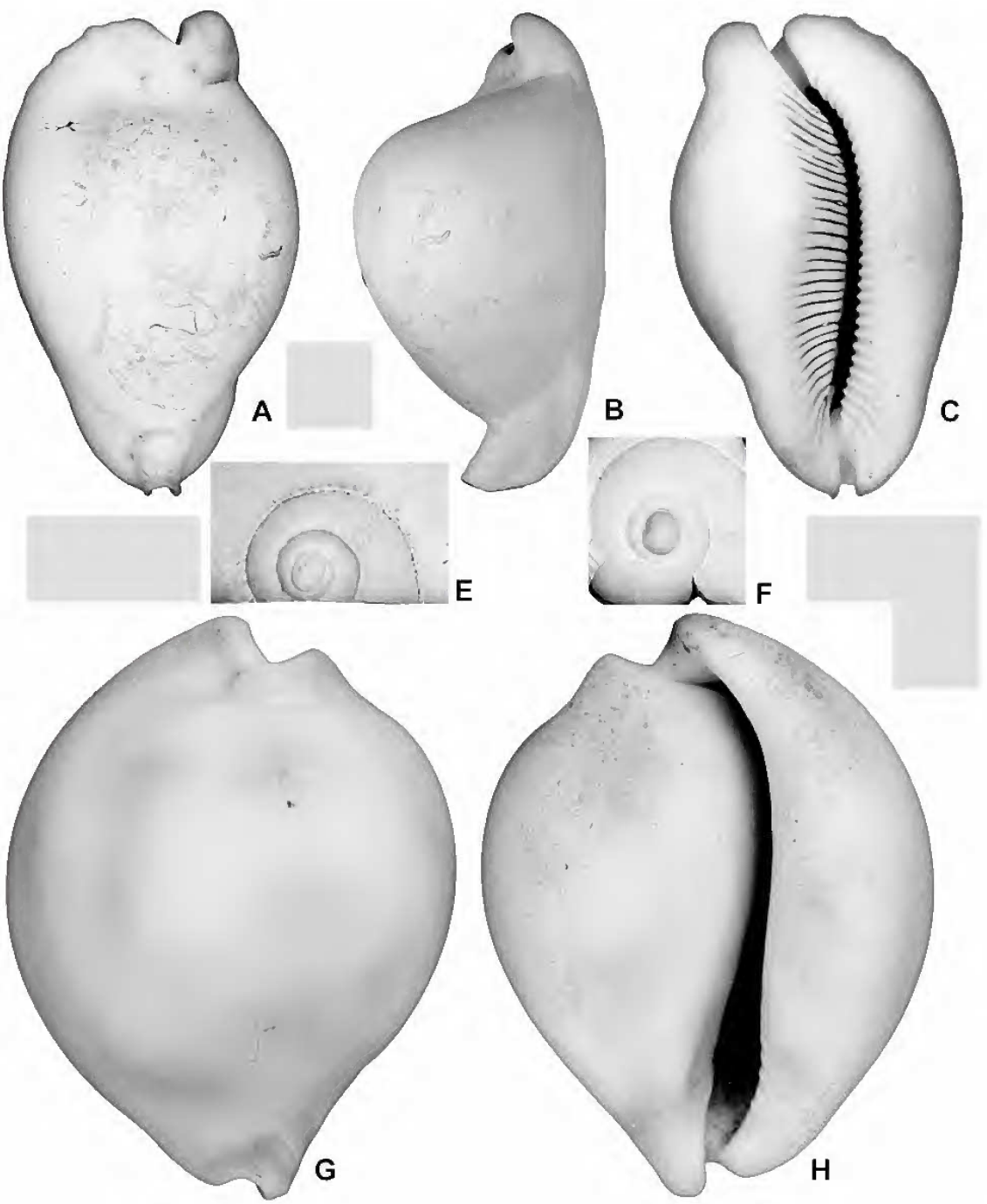

Figure 13. A–C, *Zoila platypyga*, P304415, PL 3078, × 1; E–H, *Z. gigas*; E, protoconch, P308804, Muddy Creek, × 2.5; F, protoconch, P308807, Batesford Quarry, × 2; G–H, holotype of *Cypraea dorsata* Tate, SAM T849, Muddy Creek, × 1.

less developed lateral flanges and a less projecting spire. The posterior extremity was bent to the left. These differences in callus development are minor intraspecific variations, as the specimens illustrated in figs. 11–13 show. Schilder stated that it bore a resemblance to *Z. consobrina* and that it came from a younger horizon than the latter. In fact, the holotype of *consobrina* comes from the same stratigraphical horizon.

Zoila gigas McCoy, 1867

Figures 2B, 13E–H, 14A–H, 15A–E

Cypraea gigas McCoy, 1867a:18.— McCoy, 1867b:194.— McCoy, 1867c:438.

Cypraea (Aricia) gigas McCoy.— McCoy, 1875:19, pl. 15; pl. 16, fig. 2; pls. 17–18, fig. 1; — McCoy, 1876, p. 35, pls. 28–29, fig. 1.

Cypraea dorsata Tate, 1890:212.— Tate, 1892, pl. 10, fig. 4; pl. 11, fig.6.

Cypraea (Erosaria) gigas McCoy.— Harris, 1897:208.

Cypraea gabrieli Chapman, 1912:190, pl. 13, figs 1–3.

Gisortia gigas (McCoy).— Vredenburg, 1927:58.

Gisortia dorsata (Tate).— Vredenburg, 1927:58.

? *Gigantocypraea gigas* (McCoy).— Schilder, 1930:126, fig. 34-5 (cast).

Zoila (Gigantocypraea) gigas (McCoy).— Schilder, 1935:337, 338, fig. 17. — Wilson and Clarkson, 2004:53, pl. 57.

Zoila (Gigantocypraea) dorsata (Tate).— Schilder, 1935:337, 338.

Description. Shell solid, very large for genus, globose, covered with glaze, humped at dorsal midpoint of shell. Ventral surface flat to slightly concave on most specimens. Spire scarcely projecting, covered with thick callus. Four teleoconch whorls. Protoconch of two whorls, the first depressed, large, irregular, with finely granulated surface, coiled at an angle to axis of teleoconch whorls. Posterior canal bounded by very thick walls, deeply incised, strongly reflexed dorsally, deeply notched. Anterior canal short, about same length as posterior canal, narrow, deeply incised, strongly reflexed dorsally. Aperture very sinuous, widest at beginning of anterior canal; outer lip with 2–28 teeth, on most specimens only extending to midpoint of lip. Columellar lip edentulous. Fossula scarcely differentiated from columellar lip, relatively small, slightly depressed, somewhat rectangular, extending only slightly into aperture, bounded by very weak terminal ridge.

Dimensions.

	L	W	H	LT	CT
Lectotype P12139	212	143	109	8	–
SAM T849	99	76	65	7	– holotype *C. dorsata*
P12366	135	98	72	–	– holotype *C. gabrieli*
Figured specimen P13060	167	108	90	18	– Grices Creek
Figured specimen P308774	197	138	98	12	–
P308679	145	102	91		
P12969	247	174	126 largest specimen in collection.		

Type locality. 'Blue clay of Muddy Creek, 10 miles south of Hamilton', (i.e. PL3082 Clifton Bank, Muddy Creek, 7 km west of Hamilton, Victoria). AMG Coleraine WD 818225. Muddy Creek Formation. Balcombian, Middle Miocene.

Type material. Lectotype P12139, presented Lindsay Clarke. McCoy's figured specimen chosen as lectotype.

Holotype of *Cypraea dorsata* Tate, SAM T849, Muddy Creek, Ralph Tate collection.

Holotype of *Cypraea gabrieli* Chapman, P12366, Bird Rock cliffs, presented by C.J. Gabriel, 3 April 1912.

Figured specimen P13060, presented W.H. Gregson 14 April 1919; figured specimen P308774, collected F.P. Spry 1922.

Time range. Janjukian–Bairnsdalian, Late Oligocene–Middle Miocene.

Occurrence and material. Janjukian. Jan Juc Formation: Bird Rock cliffs, Torquay (P308679, P308801, one specimen and one fragment); Deadmans Gully, Torquay (P315577, one specimen).

Batesfordian.

Gellibrand Formation: PL3047 cutting Princetown-Simpson Road (P308786, one fragment).

Balcombian

Muddy Creek Formation: Muddy Creek (P12969, P219370, P61265, P308774, P308794, P308780, P308772-3, 11 specimens); PL3082 Clifton Bank (P308776, P308795, two specimens).

Gellibrand Formation: Southeast of Gibson Beach (P54362, P308682, two specimens).

Fyansford Formation: PL3078 Fossil Beach (P308677, 308779 two specimens); Balcombe Bay (P308683-5, three specimens); Mornington (P308782, one specimen); Schnapper Point (P24866, P30777-8, three specimens); Port Phillip (P308781, one specimen); Altona Bay Coal Shaft (P308787, one fragment); Batesford (P308790, one specimen); Overburden, Batesford Quarry (P303315, one specimen and one fragment); Orphanage Hill (P308784, one specimen).

Morgan Limestone: Broken Cliffs opposite Waikerie, Murray River Cliffs, South Australia (private collection, Mannum).

Bairnsdalian

Gellibrand Formation: Glenample Steps (P308771, one specimen); Princetown (P5288, one specimen).

Fyansford Formation: Grices Creek (P5286, P12968, P12970, P13060, P308681, five specimens); Middle beds, Grices Creek (P308680, one specimen); Murgheboluc (P308678, one specimen).

Casts of a large cowry — which, due to their size, are almost certainly this species — have been found as follows:

Longfordian?

Gambier Limestone: Mount Gambier (P61262, one specimen, BM(NH) one specimen).

Batesfordian.

Curlewis Limestone: Curlewis (P308806, one specimen).

Balcombian

Nullarbor Limestone: 5 km south of Watson Station, South Australia (P316748, one specimen).

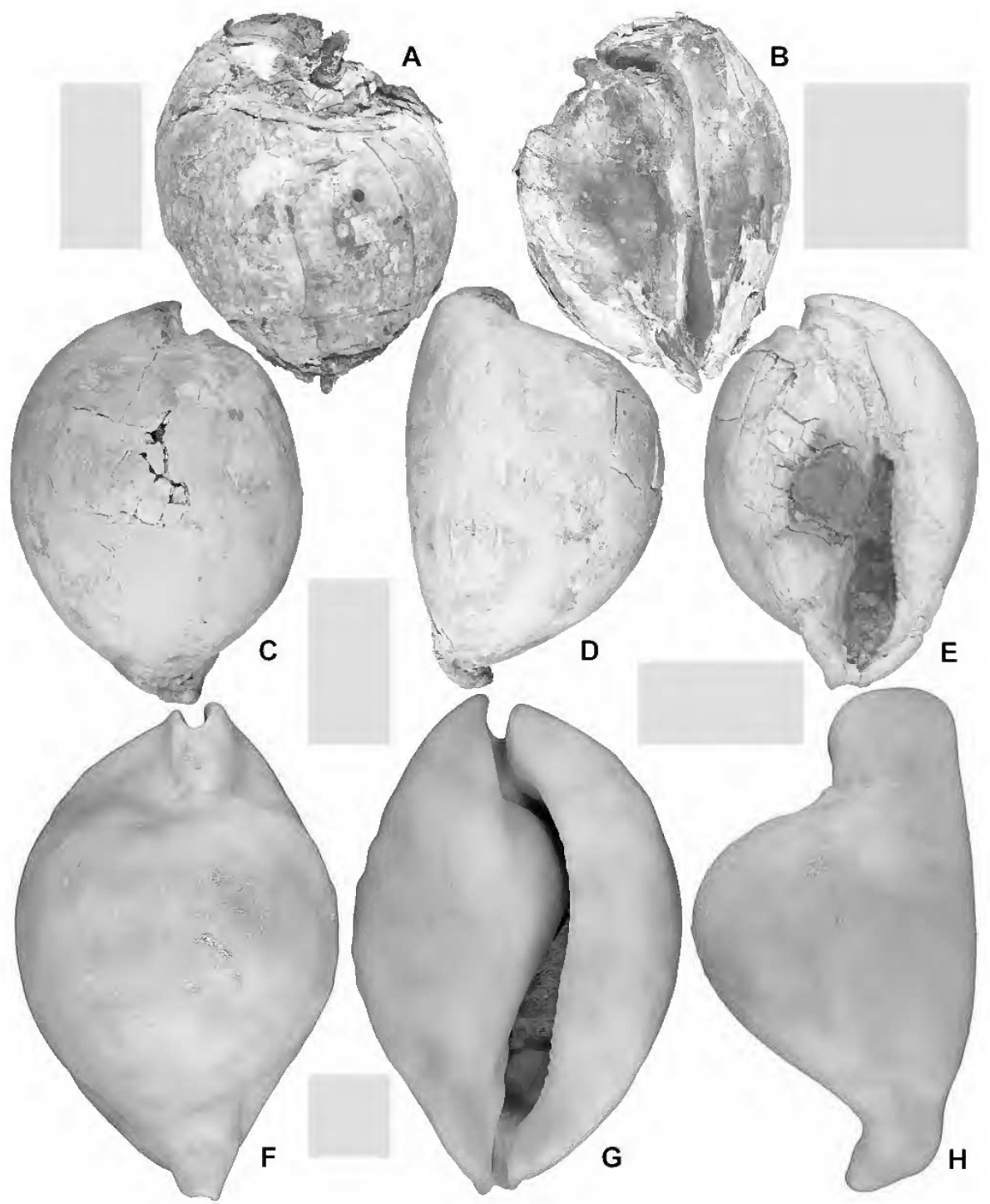

Figure 14. A–H, *Zoila gigas*; A–B, holotype of *Cypraea gabrieli* Chapman, P12366, Bird Rock cliffs, Torquay, × 0.5; C–E, P308679, Bird Rock cliffs, × 0.5; F–H, P13060, Grices Creek, 0.5.

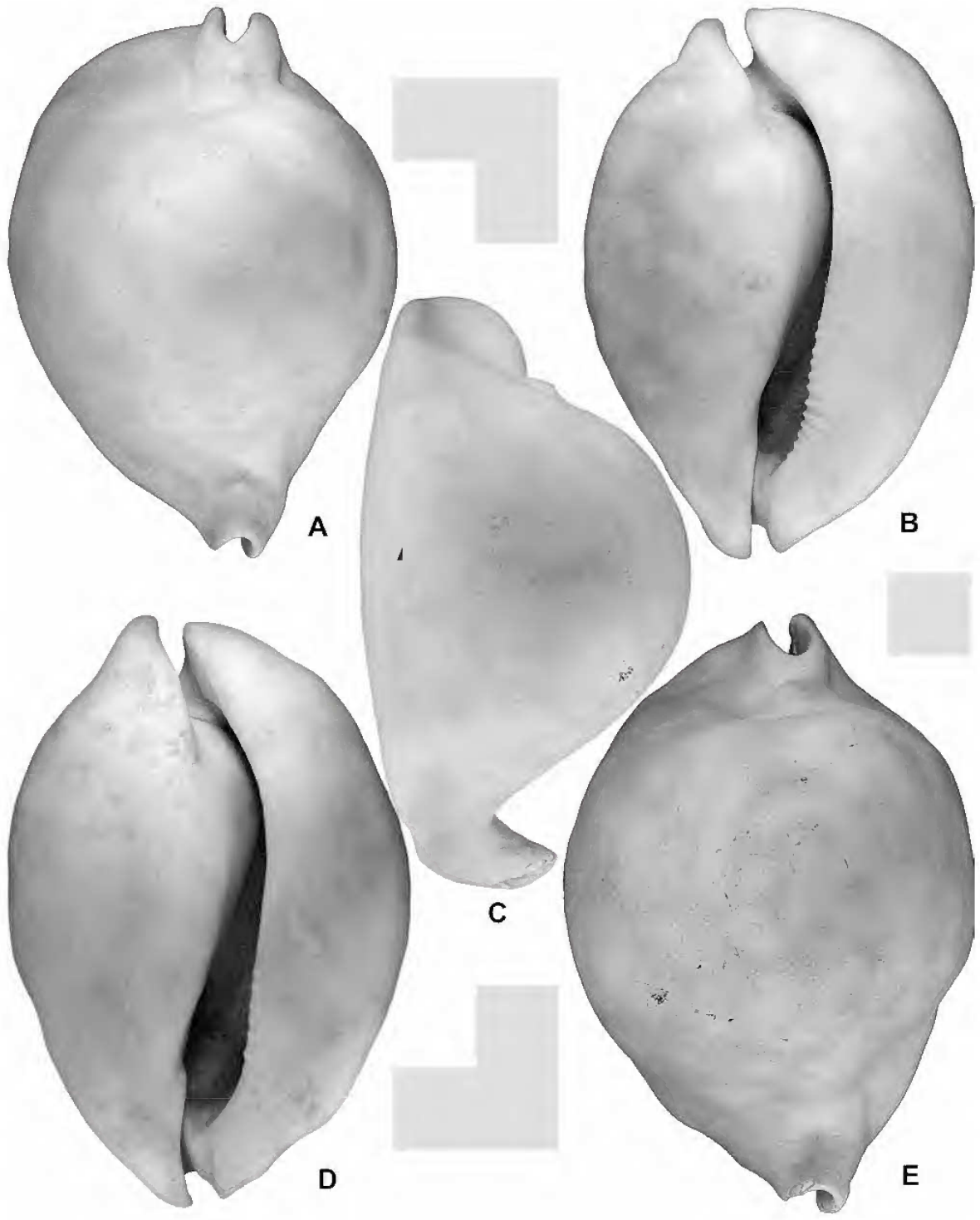

Figure 15. A–E, *Zoila gigas*; A–B, P308774, Clifton Bank, × 0.5; C–E, lectotype, P12139, Muddy Creek, × 0.5.

Fyansford Formation: Keilor (P58646, one specimen); sewerage excavation, Belmont (P308688, one specimen).

Gippsland Limestone: Newmerella Railway cutting (P308686, one specimen).

Morgan Limestone: Blanchetown (P316749, one specimen); 'Brittan', Murray River cliff 4.8 km downstream of Morgan (P316751, one specimen).

Remarks. This is the largest known Australian cowry, living or fossil. Specimens over 190 mm in length are not uncommon. Specimens are quite common in the middle Miocene, but because of their size, complete or undamaged specimens are uncommon. *Cypraea dorsata* Tate is merely a small specimen of *Zoila gigas*. The general shape, fossula and aperture are the same. The main difference is that the anterior and posterior canals are more strongly developed in most large specimens of *Z. gigas*. Small specimens, like the type of *C. dorsata*, occur with larger specimens at Fossil Beach, Grices Creek, Muddy Creek and Batesford Quarry, and there are also gradations between the smallest and the largest specimens. For these reasons, *C. dorsata* is synonymised with *Z. gigas*.

Cypraea gabrieli Chapman was based on a crushed specimen from the Jan Juc Formation, which is very difficult to compare with other material. The main differences between it and the lectotype of *Z. gigas* McCoy are a depressed spire, the lack of callus covering the spire and the presence of a dimpled dorsum. Only one other specimen from the Jan Juc Formation is available. This is complete and uncrushed, but has a very chalky shell. There are well-developed teeth on the outer lip extending to about midway on the lip. On the columella there are some very low but distinct teeth situated over the fossula and about midway along the aperture. The dorsum is smooth and the base is rounded rather than flat or convex. Apart from the presence of the columellar teeth, this specimen closely matches a similar-sized specimen from the Fyansford Formation at Grices Creek in all features including the spire and fossula. McCoy pointed out there were weak teeth just visible on the columella of the holotype of *Z. gigas*. The significance, if any, of the presence of the dimpled dorsum cannot be assessed as there are so few specimens. Because there are no consistent differences between the two specimens from the Jan Juc Formation and specimens of *Z. gigas* from the Fyansford Formation, *Cypraea gabrielli* is regarded as a further synonym of *Z. gigas*.

The protoconch of this species (figs 2B, 13E–F) is different from those of other species of *Zoila* and also from those of species of *Umbilia*. There are fewer whorls and the first is irregular in shape, suggesting that it might originally have been chitinous and subsequently calcified. Other species of *Zoila* are similar to species of *Umbilia* in that they have a smooth, regular protoconch of three whorls, and a coiling axis at an angle to that of the teleoconch.

Zoila sp.

Figures 16C–D, M

Zoila sp. McNamara and Kendrick, 1994:34.

Description. Shell solid, small for genus, somewhat globose. Spire covered with callus, not projecting. Posterior canal short, notched. Anterior canal missing; slight trace of anterior basal extension on left flank. Aperture narrow, very slightly curved; outer lip with well-developed, elongate teeth (15 teeth preserved). Columellar lip with well-developed teeth extending along the whole aperture (18 teeth preserved). Base of shell rounded on both sides of aperture. Fossula well developed, concave, broad and spoon-shaped, bounded anteriorly by well-developed, single terminal ridge.

Dimensions.

	L	W	H
Figured specimen WAM 82.549	48+	36	30

Figured material. WAM 82.549, collected K. J. McNamara and G. W. Kendrick, September 1981.

Occurrence. Locality 12, Latitude Point, from large boulders of pink limestone fallen from upper level of cliff, Barrow Island, Western Australia. Poivre Formation, middle Miocene.

Remarks. This species is known only from a single specimen, which has a small piece of the left side of the posterior canal broken off, as well as a large portion of the right side of the anterior end, including the posterior canal. As a consequence, detailed comparison with other species is not possible; however, there is enough of the specimen preserved to indicate that it is a species of *Zoila* and almost certainly ancestral to the younger species occurring in Western Australia. Both aperture and fossula are very similar to those of *Z. campestris* sp. nov. from the late Pliocene, Roe Calcarenite. It differs from *Z. campestris* in that its outline is more rounded and it does not have a flat base. The dorsum is also not humped anteriorly as in *Z. campestris* sp. nov. It bears no close resemblance to any of the fossil species known from southeast Australia.

Zoila sp. is somewhat similar to the middle Pliocene species *Zoila gendingensis* (Martin, 1899) from the Upper Kalibeng Formation of Sonde, Java, Indonesia, but is not so high and does not have the flat base of that species. The dorsum is not as humped as in *Zoila kendengensis* Schilder, 1941 from the Pleistocene Putiangan Formation of Java and neither does it have the flat base of that species. Of the living species of the genus, it is most similar to *Zoila venusta* (Sowerby, 1846), known from the Great Australian Bight to Shark Bay, Western Australia.

Zoila campestris sp. nov.

Figures 16A–B, E–J, O

Cypraea (Zoila) sp. Ludbrook, 1978, p. 129, pl. 13, fig. 19.
Zoila sp. Wilson and Clarkson, 2004: 52, pl. 55, figs a, b.

Description. Shell solid, polished, of average size for genus, globose, surface on some specimens malleated with rectangular depressions, with sides about 1.5 mm long; ventral surface flattened. Spire barely protruding beyond last whorl, covered with thick callus. Posterior canal short, notched, sides thickened. Anterior canal very short, abruptly truncated, deeply incised. Aperture sinuous, widened above fossula; outer lip with 17–24 well-developed teeth, extending along entire lip;

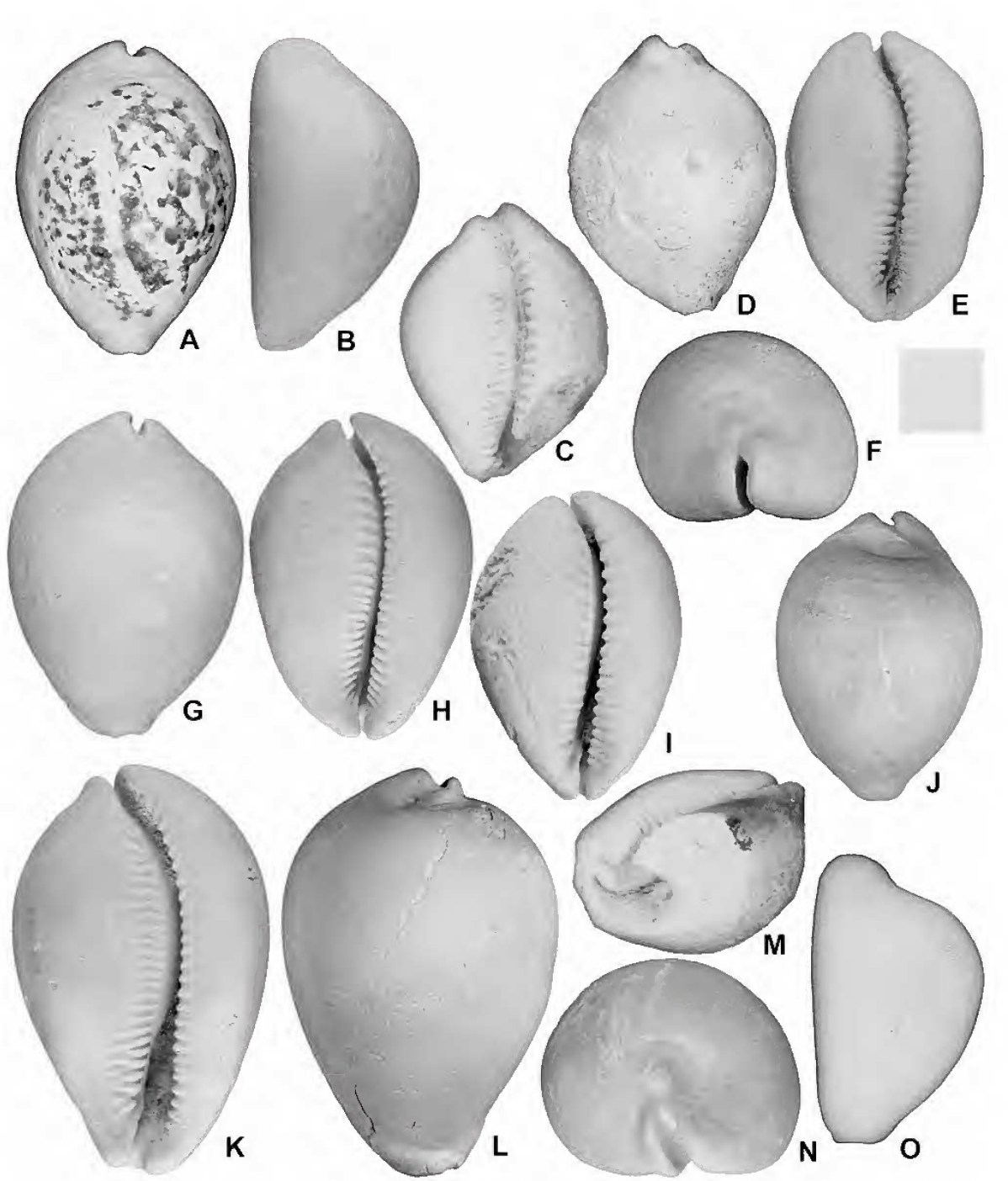

Figure 16. A–B, E–J, O, *Zoila campestris*; A–B, paratype, WAM 89.437, Roe Plain, Western Australia, uncoated to show colour pattern, × 1; E, J, O, paratype, P308704, Roe Plain, × 1; F–H, holotype, WAM 89.177, Roe Plain, × 1; C–D, M, *Z.* sp., WAM 82.549, Barrow Island, Western Australia, × 1; K–L, N, *Z. fodinata*, holotype, WAM 89.637, Roe Plain, Western Australia, × 1.

inner lip with 17–21 well-developed teeth, extending along entire lip. Fossula well developed, deeply depressed, bounded anteriorly by sharp terminal ridge. Colour pattern present on some specimens, of brown ground with darker brown patches.

Dimensions.

	L	W	H	LT	CT
Holotype WAM 89.177	57	41	34	27	21
Paratype WAM 89.437	55	38	30	18	18
Paratype NMV P308704	51	36	30	20	19

Type locality. Quarry 2.5 km north of Hampton microwave repeater tower, Roe Plains, Western Australia. AMG Eucla l:250,000 sheet CK365465. Roe Calcarenite.

Type material. Holotype WAM 89.177, collected G.W. Kendrick 27–30 October 1988; paratype WAM 89.437, collected Sam Rowe, January 1989; paratype NMV P308704, collected T. A. Darragh, 9 August 1973.

Time range. Pliocene.

Occurrence and material. Roe Calcarenite: PL3172 Hampton Tower (P308704-5, WAM 69.494, 70.17, six specimens); PL3167 1.5 km north of Hampton Tower (P308703, WAM 80.109, three specimens); PL3166 2.5 km north of Hampton Tower (P121293, WAM 89.178, 89.437, 89.637, four specimens).

Remarks. At first glance, small specimens of this species may be confused with the common *Austrocypraea amae* Fehse and Kendrick of the Roe Calcarenite, but they are readily distinguished by their smooth fossula. In *Austrocypraea*, the columellar teeth are produced into thin ribs that continue across the fossula. This species is most closely related to the living species *Zoila decipiens* (Smith, 1880), Recent, Western Australia, from which it differs by having stronger teeth and teeth present along the entire columella. It is also globose in shape rather than pyriform as in *Z. decipiens* and lacks the prominent protruding spire of that species. The fossula is very similar to that of the *Z. decipiens*. It is not closely similar to the fossil species of *Zoila* known from the Oligocene and Miocene of southeast Australia, with the exception of a species known from a single broken specimen from the upper Miocene of Victoria. *Z. campestris* bears some resemblence to *Zoila kendengensis* Schilder, 1941 from the Pleistocene Putiangan Formation of Java, but that species has relatively prominent anterior and posterior canals.

Etymology. Latin campester, pertaining to a plain.

Zoila fodinata sp. nov.

Figures 16K–L, N

Description. Shell solid, polished, of average size for the genus, globose, pyriform, ventral surface rounded. Spire slightly protruding beyond last whorl, covered with thick callus. Posterior canal short, notched, sides thickened. Anterior canal very short, abruptly truncated, deeply incised. Aperture sinuous, widened above fossula; outer lip with 25–28 well-developed teeth, extending along entire lip; inner lip with 21–25 well-developed teeth, extending along entire lip. Fossula well developed, subrectangular, concave, bounded on inner side by low ridge and anteriorly by sharp terminal ridge; terminal ridge rather broad, extending down into aperture as sharp ridge forming anterior edge of fossula.

Dimensions.

	L	W	H	LT	CT
Holotype WAM 89.637	72	47	39	28	24

Type locality. Quarry 2.5 km north of Hampton microwave repeater tower, Roe Plains, Western Australia. AMG Eucla l:250,000 sheet CK365465. Roe Calcarenite.

Type material. Holotype, WAM89.637, collected G.W. Kendrick, 27–30 October 1988.

Time range. Pliocene

Occurrence and material. Roe Calcarenite: PL3166 2.5 km north of Hampton Tower (one specimen).

Remarks. This species is most closely similar to the living species *Zoila venusta*, from which it differs by having stronger teeth and teeth present along the entire columella. The fossula is also shallower but deeper within the aperture than in *Z. venusta*. It is not as globose, being more pyriform. It does not seem to be closely similar to the fossil species of *Zoila* known from the Oligocene and Miocene of southeast Australia.

Etymology. Latin, fodina, a quarry.

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